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SOME GOLD AND TUNGSTEN DEPOSITS OF BOULDER COUNTY, COLORADO.[1]

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INTRODUCTION

Boulder County has long been known as an important producer of gold and silver. Its deposits form the extension of the gold-bearing belt of Clear Creek and Gilpin Counties, and reach from the southwestern corner of the county well up towards the center. A number of silver deposits were worked in the early days, among which the most prominent was the Caribou mine, but for many years the principal attention has been given to gold. The county is distinguished by a steady, although not very large gold production, and has a great number of small mines. Many of its deposits contain tellurides, and comparatively few of them are of free-milling type. In recent years important deposits of wolframite have been discovered in the southwestern part of the county, especially near Nederland, and the output of this ore has reached very considerable figures. While no exact statistics are available, it is believed that the output of this tungsten ore in Boulder County reached a value of $350,000 in 1905, and the industry gives good assurance of permanency.

The mineral wolframite, a tungstate of iron and manganese, contains the metal tungsten, which is used as a steel-hardening

[1] Published by permission of the Director of the U. S. Geol. Survey.

material. It is in good demand at prices up to $12 per unit of tungsten-trioxide, making 70 per cent. ore worth $840 per ton.

The following paragraphs describe some of these gold and tungsten deposits in the southwestern part of the county, in the vicinity of Eldora and Nederland, from data obtained during a short visit to the county in 1906. The mineral deposits of Gilpin County have been briefly described by G. H. Garrey in Bulletin No. 285, pp. 35–40. The gold and silver deposits of Clear Creek County have been described by Messrs. Spurr and Garrey in Bulletin No. 260, U. S. Geological Survey, pp. 99–120, and a more complete report is now in press. On the other hand, very little has been published in the way of a geological description of the Boulder County mines. Mr. T. A. Rickard has briefly mentioned some of the deposits in a paper entitled, "The Veins of Boulder and Kalgoorlie," in the *Transactions of the American Institute of Mining Engineers,* Vol. XXXIII., 1903, pp. 567–577.

SITUATION.

The narrow gauge road which ascends into the mountains from Boulder follows the canyon of a fork of Boulder Creek westward as far as Sunset, and then winds its way up the hills at steep grades to its terminal point at Eldora, on the Middle Fork of Boulder Creek. Eldora is situated at an elevation of about 8,700 feet, in the narrow glacial valley of Middle Fork, the ridges rising on each side from 1,000 to 1,500 feet above the little town. Going upstream from Eldora the elevations increase rapidly, and in a few miles the Continental Divide, with elevations of from 12,000 to 13,500 feet, is reached. Going downstream the valley soon widens and at Nederland, some four miles below Eldora, the forested hills surrounding it are much more gentle and covered by disintegrated granite. The elevation of Nederland is about 8,000 feet.

GENERAL GEOLOGY.

As in Gilpin and Clear Creek Counties, the prevailing rocks are pre-Cambrian, and consist of granites, gneisses, and schists.

The oldest rocks appear to be biotite and amphibolite schists and gneisses. Into these rocks, the schistosity of which varies considerably in strike and dip, great masses of medium-grained, light-colored granite have been intruded and injected in the most complicated manner. The injection of the granular rock chiefly follows the planes of schistosity, but often also breaks across them. The relations of the two rocks show excellently on the steep and bare rock walls near Eldora. The granite is often pegmatitic, and smaller well-defined pegmatite veins composed of quartz, orthoclase, and white mica, are very common. The pegmatite dikes appear in places to have contact-metamorphosed the amphibolitic schists, for lighter-colored zones a few inches wide often surround these dikes and seem to be produced by the absorption of the hornblende by the intruding magma.

The amphibole schists in places contain segregations of quartz, with epidote and a little pyrite. These segregations are older than the pegmatite dikes which cut across them.

Narrow dikes of porphyry are found in various places along the mineral belt, but their outcrops are hardly ever visible. As exposed in the mines the porphyries are of several kinds, but none thus far encountered are very siliceous. In the Mogul tunnel at Eldora a large porphyry dike occurs about 1,000 feet from the portal. This is a grayish-green rock, very hard, and containing many small, closely crowded feldspar crystals. The phenocrysts consist of small idiomorphic triclinic feldspars, too much sericitized for determination. There are also abundant grains of magnetite and epidote, with some chlorite, the latter two minerals evidently the remains of biotite, hornblende, or augite. The groundmass is microgranular and appears to consist of feldspar, with some quartz.

In the mines of the Wolftongue Tungsten Company a fine-grained porphyritic rock cuts the granite. It is extremely sericitized so that the original character is somewhat doubtful. The phenocrysts consist of small foils of muscovite, accompanied by a little rutile, and evidently represent altered primary biotite. The groundmass is fine-grained and consists chiefly of feldspar, probably orthoclase.

On the whole, these rocks belong in the groups of the monzonite-porphyry or syenite-porphyry. They are distinctly earlier than the mineral deposits in connection with which they occur.

Effusive rocks, such as basalts, rhyolites, and andesites, are entirely absent.

MINERAL DEPOSITS.

The gold belts of Clear Creek, Gilpin and Boulder Counties are not arranged along any one definite line, although their general trend is northeasterly. The veins, as a rule, can not be traced far. The veins of Central City, in southern Gilpin County, trend northeasterly, but no deposits are found in their further extension in that drection. Other veins appear, however, in the northern part of the county, near Tolland and Rollinsville, but even these do not directly extend into Boulder County. A further offset towards the north takes place and at Eldora and Caribou short veins trending northeast or east-northeast again appear to be succeeded in the central portion of the county by a great number of more or less parallel vein zones ranging over a width of fifteen or twenty miles. Near Jamestown the most northerly veins are found and still farther in this direction the granitic rocks appear to be barren.

The ore deposits in the county are of three kinds, first, the sulphide veins; second, the telluride veins; and third, the tungsten veins.

Sulphide Veins.—The sulphide deposits are in general regular quartz veins containing gold and silver-bearing sulphides, principally pyrite, galena, chalcopyrite, and zinc-blende. Most of them contain a considerable proportion of silver, besides gold, and in some the silver predominates entirely. As an example of the gold-bearing veins may be cited the Boulder County mine, which is located near the Caribou station, a few miles northeast of Eldora. This is an old-time producer of considerable importance which has recently been opened by a deep tunnel 3,200 feet in length, exposing a vein 500 or 600 feet below the old workings. The regular and well-defined vein consists chiefly of

quartz, with zinc-blende, galena, chalcopyrite, and some molybdenite. The ore is treated by concentration in a stamp mill.

Another mine belonging to this class is the celebrated Caribou mine, which is one of the old-time producers of Boulder County. It is reported that up to 1880 the mine had yielded $1,168,000. The mine has been opened by a main shaft to the 800-foot level, and the developments in general are extensive. The ore was formerly reduced in a silver mill, located at Nederland, by chloridizing roasting in Bruckner furnaces, followed by pan amalgamation. The mine has been idle for many years, although it is not impossible that at the present prices for silver a reopening may be attempted.

Telluride Veins.—Many gold deposits of Boulder County contain tellurides, and these minerals were, in fact, identified from this county long before Cripple Creek was discovered. The best known property of this kind near Eldora is the Enterprise vein, the croppings of which may be seen near the summit of Spencer Mountain, and which in former years yielded a considerable amount of gold. A large chlorination mill was erected some years ago half a mile above Eldora, to treat the ores of this deposit, but it was only in operation for a short time. There are several other veins cutting the granite of Spencer Mountain, and most of them are parallel to the Enterprise vein. All outcrops of the deposits are very inconspicuous and more likely to be indicated by little saddles and depressions on the ridges than by prominent croppings. The strike of the veins is a little to the north of east. The Enterprise mine is opened near the summit of the mountain by a shaft 400 feet in depth, with 200 feet of water standing in it at present. Some prospecting work was going on in the upper levels in 1906.

The Mogul tunnel at Eldora, 900 feet below the croppings of the Enterprise vein, cuts a number of parallel veins, most of which belong to the telluride class; some of them, however, are regarded as belonging to the sulphide veins. The tunnel cuts the eastern extension of the Village Belle, which is thought to be the extension of the Enterprise. Disputes between the

owners of the tunnel and the mining companies are said to stand in the way of the successful working of the deposits in Spencer Mountain. No accurate data as to the production of these veins are available. A considerable amount was, as stated, obtained from the upper portion of the Enterprise vein, and in the tunnel much stoping has been done along one of the telluride veins for a distance of about 400 feet. It is believed that the sulphide veins are later than the telluride veins, and one instance was noted in the Mogul tunnel which seemed to confirm this, but the subject requires further examination.

The structure of the telluride veins has been briefly and accurately described by Mr. T. A. Rickard. In general, the veins consist of several narrow seams forming a more or less regularly sheeted zone, along which partial filling and some replacement have taken place. A gouge separating the vein from the country rock on one side is sometimes present, but more commonly the vein is "frozen to the wall" and the vein matter changes gradually into the country rock. The width of the vein is usually confined to from one to three feet. Within the sheeted zone crushed rock very commonly appears partly cemented by the vein matter. Vugs are of very frequent occurrence and really characteristic of the deposits. Crystals of the gangue very frequently project into the vugs.

The ores contain chiefly gold, with very little silver, and the principal valuable mineral is a telluride of gold believed to be sylvanite. The tellurides usually occur in a flinty vein matter or in the greenish roscoelite distributed as small specks, hardly ever as well crystallized minerals. Pyrite is present in small amounts, chiefly as small grains in the altered country rock. Molybdenite occurs in abundance, but is usually extremely fine-grained, and intergrown with barite. On the dump its presence is indicated by deep blue stains on the ore fragments. This blue molybdenite stain, to which attention has been drawn in the Cripple Creek report,[1] is believed to be the rare mineral, ilsemannite, a compound of the oxides of molybdenum ($MoO_2.4MoO_3$).

[1] Professional Paper No. 54, U. S. Geol. Survey, pp. 114, 123.

Characteristic among the gangue minerals of the telluride veins are barite, quartz, roscoelite and chalcedony. The quartz occurs in moderate amounts, and more frequently chalcedony takes its place, forming jasperoid masses of brown or black color, locally called hornstone. Barite is also very abundant and often appears crystallized in small and thin plates.

Mr. Rickard, in the article mentioned, has called attention to the general occurrence of roscoelite in the Boulder County mines—an interesting fact not elsewhere recorded. Roscoelite is very abundant in the ores of the Mogul tunnel and the Enterprise mine. It forms dark yellow-green masses intergrown with quartz or irregularly distributed in the ore, and, as stated above, very frequently contains specks of gold tellurides. Sections of this greenish material show the roscoelite as minute greenish-yellow scales of micaceous character, intergrown with pyrite in small crystals. This mixture of roscoelite and pyrite is surrounded and invaded by a later deposited mass of fine granular quartz, with some adularia in the rhombic crystals which are so characteristic in the variety of this mineral called valencianite.

Thin sections of the crusted ore show that the granitic rock on which it was deposited is extensively altered to fine scales of sericite, and in part also replaced by grains of barite. Neither calcite nor chlorite are present, but a little pyrite is distributed through the partially altered granitic rock. The crusted material consists of tabular crystals of barite, on which a layer of very fine-grained molybdenite is deposited. This again is covered by concentric deposits of chalcedonic silica. Next to the crust the silica is of a brownish color, but gradually lightens towards the center, in which large barite crystals are contained. Another specimen of country rock, originally an amphibolitic schist, is found to be converted into a greenish-gray soft rock which chiefly consists of extremely fine and felted sericite, with a little iron pyrite.

Summing up these statements, it will be seen that the telluride veins at Eldora have a very remarkable structure and composition. The structure is characterized by narrow shear zones, vug

holes, and incomplete deposition. The characteristic minerals are gold tellurides, molybdenite, roscoelite, barite, adularia, and chalcedonic silica. The intimate relationship to the Cripple Creek veins is clearly apparent, and the structure, here as there, points to deposition comparatively near the surface. These deposits are emphatically not formed at great depths. The original surface can not have been much different from that general surface of erosion which is marked by the high ridge lines of this part of the Rocky Mountains, and which is supposed to be of late Tertiary age.

Tungsten Veins.—The tungsten mines of Boulder County are situated within a mile of the town of Nederland. The ores do not contain any notable amounts of gold and silver, and the deposits are themselves, at first glance, entirely distinct from the gold and silver veins. Near Sugar Loaf, a half mile to the northeast of Nederland, some gold veins exist which are reported to carry tungsten also, a fact which in no way is surprising, since compounds of tungsten are not uncommon in gold-bearing and silver-bearing veins. A great number of small tungsten veins occur in the vicinity of Nederland. The principal deposits are, however, located on the timbered and moderately high ridge about half a mile north of the town. During 1905 much of the ore shipped came from near the surface, where it was necessarily enriched by a process of natural concentration. At the present time attempts are made to follow the veins in depth by tunnels or shafts. As stated above, the total production is estimated to have had a value of $350,000 in 1905, and the production for 1906 will probably not fall far short of that figure. Much of the ore shipped has been simply hand-picked, but in most cases a wet concentration is needed in order to bring the ore up to the requisite percentage of tungsten.

The Wolftongue Mining Company, of Pittsburg, have erected a twenty-stamp mill at Nederland, with five Wilfley tables and six slime tables. In the summer of 1906 chiefly custom ores were treated in this mill. It is estimated that the world's output of tungsten ore in 1905 was about 3,000 tons. Of this amount,

Boulder County contributed perhaps one third, or 1,000 tons. The deposits occur in a coarse-grained, granitic rock injected into biotite and hornblende schist just as at Eldora. The exposures on the rounded hills surrounding the town are, however, much poorer than at the first mentioned place. The deep mining has revealed the presence of a strong dike of syenite-porphyry or monzonite-porphyry, which appears to be followed by the vein.

The deposits are well-defined fissure veins from a few inches to six feet in width, striking about north and south and dipping at steep angles.

The three most important mines are situated on a granite ridge about half-way between Nederland and Tungsten Siding on the railroad. The Wolftongue Mining Company owns the Oregon mine, now 200 feet deep, in which some exploratory work was in progress in 1906. Adjoining this and a little to the north, is the Boulder County tungsten mine, which was closed down at the time of visit. A third mine is located on a parallel vein a few hundred feet to the west, and is owned by the Colorado Tungsten Company. This mine is opened by a vertical shaft 300 feet in depth, and development work was progressing at the time of visit. The Wolftongue Company owns a number of smaller mines, among which the Clyde and the Hosea are the most important.

The veins form narrow shear zones, in which open vugs coated with quartz and wolframite crystals are very common. Extensive shattering has also taken place in some places after deposition, and has been followed by re-cementation by silica. Wolframite, poor in manganese and entirely opaque in thin section, is practically the only ore mineral present. "Graphite" is reported to have occurred in some batches of ore mined by the Wolftongue Company. It is more likely that this so-called graphite is molybdenite. Small specks of pyrite occur in the decomposed country rock and in the wolframite, but on the whole is very inconspicuous. No other ore minerals have been noted. The principal gangue mineral is quartz, most of it fine-grained. It contains microscopic inclusions of cubical, colorless crystals, probably iso-

tropic, which were thought to be fluorite. This was not, however, confirmed by a careful chemical test for fluorine. The country rock, whether granite or porphyry, is, adjoining veins, rather strongly sericitized but contains no calcite or any other mineral except a little pyrite. The hornstone, or chalcedonic silica, so characteristic of the Eldora veins, does not occur here. In some places, however, the country rock next to the vein has apparently been silicified, and now looks like a dark-gray, fine-grained quartz. The principal ore from the deep levels consists of narrow stringers of a fine-grained intimate mixture of wolframite and quartz, which requires fine crushing for the purpose of concentration. The vugs are frequently lined with wolframite crystals, some of them of large size and very perfect and the central cavity of the druses is often, especially near the surface, filled with a soft material resembling kaolin.

Although the filling of these veins is very different from that of the telluride veins at Eldora, there is unquestionably a strong resemblance between them as far as the structure of the vein and sericitization of the country rock are concerned, and this leads to the belief that the tungsten veins are also a product of comparatively recent thermal activity, and that they are deposited at only a moderate depth below the original surface.

Wolframite is found in pegmatite veins, in company with cassiterite, and other minerals of rarer kind. More commonly it is found in quartz-filled veins similar to the ordinary gold-quartz deposits of California. The tungsten deposits of Boulder County differ from both of these types.

Postscript.—A recent number of the *Engineering and Mining Journal* (May 18, 1907) contains an interesting and valuable article by Mr. W. E. Greenawalt on "The Tungsten Deposits of Boulder County, Colorado." It is difficult, however, to agree with the author when he characterizes the dikes as andesite, and when he finds evidence in the extensive brecciation of "igneous conditions in the formation of the deposits."

Three analyses of concentrates, given in this article, run as follows:

ANALYSES OF CONCENTRATES.

	Beaver Creek per Cent.	Nederland per Cent.	Gordon Gulch per Cent.
Tungsten trioxide	66.41	63.20	60.84
Ferrous oxide	24.31	20.36	18.36
Manganese oxide	3.25	1.10	4.73
Silicon	6.00	15.00	16.28
Phosphorus	trace	trace	.05
Sulphur	.02	.50	.20
Gold	trace	trace	trace
Silver	1.20[1]	2.40[1]	3.10[1]

[1] Ounces per ton.

TURQUOISE IN THE BURRO MOUNTAINS, NEW MEXICO.

EDWARD R. ZALINSKI.

[The following notes are from data collected during the year 1905 while the writer was superintendent of the Azure Mining Company's property near Silver City. It was his intention to make a detailed study of the subject, but this professional duties have hitherto prevented and in the following pages are presented the tentative conclusions of an unfinished investigation.]

HISTORY AND LOCALITIES.

Turquoise originally came from Persia by way of Turkey and was imported by the Venetians, who called it *Turchesa,* of which its present name is the French variation. In America it has long been known to the southwestern Indians and was used by them for ornaments and mosaic work.

Professor W. P. Blake, in 1858 and '59, called attention to its occurrence at Cerrillos, New Mexico, where it had been mined by the aborigines and early Spaniards. This locality has produced some valuable gems, but the mines are not at present worked. Turquoise has been found also at Turquoise Mountain, Cochise County, and Mineral Park, Mohave County, Arizona; near Columbus and near Crescent, in southern Nevada; in Fresno County, California; and in Colorado. In New Mexico, besides Cerrillos mentioned above, it is known at Hachiti; in the Burro Mountains, Grant County; and in the Jarrilla Mountains, Otero County.

The modern discovery of turquoise in the Burro Mountains dates from 1875, but these deposits were known to the Indians and were worked by them. Remains of ancient operations are still to be seen, while stone hammers, implements and fragments of pottery have been found near the old excavations.

The finding of turquoise ornaments and of old excavations in the Burro Mountains led to the rediscovery of the district. As

to whom the actual discovery is due, there is some dispute, but the names of John E. Coleman, W. J. Foley and Nicholas C. Rascome are all mentioned in this connection.

John E. Coleman, known as "Turquoise John," while on a hunting trip in 1875, discovered the old excavations. The first claim located was the Calliate. It covered the largest dumps and was supposed to be the best. As it proved later, the richest claims, the Santa Fe and Gem, now owned by the Azure Mining

FIG. 50. Index map showing position of the Burro turquoise district.

Company, had no prehistoric dumps to mark them. The consolidated holdings were sold to C. Armeny, of New York, who organized the Azure Mining Company in 1891; the controlling interests being held by New York jewelers, chiefly L. and M. Kahn & Co., and M. Rothschild, not Tiffany & Co., as commonly reported. The property acquired for a small amount has since produced stones to the value of several million dollars.

GENERAL GEOLOGY OF THE REGION.

Little has been published regarding the geology of the district. The turquoise deposits are situated fifteen miles southwest of Silver City. The country rock in the neighborhood of the mines is granite. Intrusive andesite porphyry and andesite and dacite dikes also occur. Across the Mangus Valley to the east are sedimentary rocks: limestone, shale, sandstone, and quartzite. To the west lies the great eruptive region in the neighborhood of Bullard's Peak.

The Burro Mountains consist largely of granite. On account of the main topographic features they are spoken of as the Big and Little Burros. The Little Burros rise in a gentle slope from the Mangus Valley, and reach an altitude of 6,500 feet. The rounded and smooth surface is cut by abrupt cañons. St. Louis Cañon in the central part and Dead Man's Cañon on the west show several abrupt drops, and afford good exposures.

The Big Burros rise from behind the Little Burros to an altitude of approximately 8,000 feet. The Mangus Valley at the Azure Mining Company's well has an elevation of 5,900 feet, and that of the turquoise deposits is 6,200 feet. The Big Burros consist of three peaks with rugged slopes.

The sedimentary beds on the east of the Mangus Valley dip away from the main granite core.

Fossils found here in the limestone and sandstone were sent to Dr. Geo. H. Girty, of the U. S. Geol. Survey, and proved to be of Cretaceous age. A specimen found several miles to the northeast belonged to the Carboniferous. Dr. Girty says:

> " The single specimen can with reasonable certainty be called Carboniferous. It differs lithologically from the shells preserved in the red sandstone, being a silicified coral, and belonging to the genus *Chætetes*, which is rather abundant at certain horizons in the Carboniferous of New Mexico."

The remainder of the fossils from the limestone and iron-stained sandstone beds on the Mangus Valley slope, two miles from the Azure mining camp, were identified by Mr. T. W. Stanton as belonging to the Upper Cretaceous. Mr. Stanton says:

"The fossils are not very well preserved and for that reason it is impossible to make definite specific determinations, but the presence of the genera *Ostrea, Inoceramus, Cardium, Mactra, Lunatia* and *Turritella,* is sufficient evidence that the rocks are of Upper Cretaceous age and the specific types represented suggest a horizon in the lower part of the Upper Cretaceous."

The gentle and uniform dip of the strata is observed for some distance. To the north the dip is not so pronounced. The overlying strata have been entirely eroded from the Burros.

The uplift took place after the Cretaceous, previous to the great volcanic activity of Tertiary times. Following the uplift and doubtless after a period of considerable erosion, andesite porphyry was intruded into the granite, and last of all andesite dikes which cut the porphyry and also the sedimentary rocks of the section. The last intrusions were undoubtedly of Tertiary age.

Fracturing and mineralization accompanied the intrusions. Copper occurs over an area three miles east and west by two miles north and south. The turquoise-bearing section adjoins this ground to the northwest and copper staining is found throughout the turquoise area. The principal copper minerals are malachite and chrysocolla. In the mines of the Burro Mountain Copper Company some high grade cuprite and chalcocite are found.

GEOLOGY OF THE TURQUOISE DEPOSITS.

The Azure mining camp is situated in the Little Burros near the summit of the Mangus Valley slope at an altitude of about 6,200 feet. Figure 51, a map prepared from a plane table survey, shows the location of the Azure mine and the geology in the immediate neighborhood of the turquoise deposits.

Granite is the country rock and for some distance surrounding the turquoise it is much altered. The feldspar is mostly kaolinized, giving the rock a light grayish color, and ferromagnesian minerals—chiefly biotite—have almost entirely disappeared. The rock when fresh shows pink orthoclase, quartz and biotite. The latter is not plentiful. When altered the feldspar is white and partly kaolinized and the rock has a porous and leached

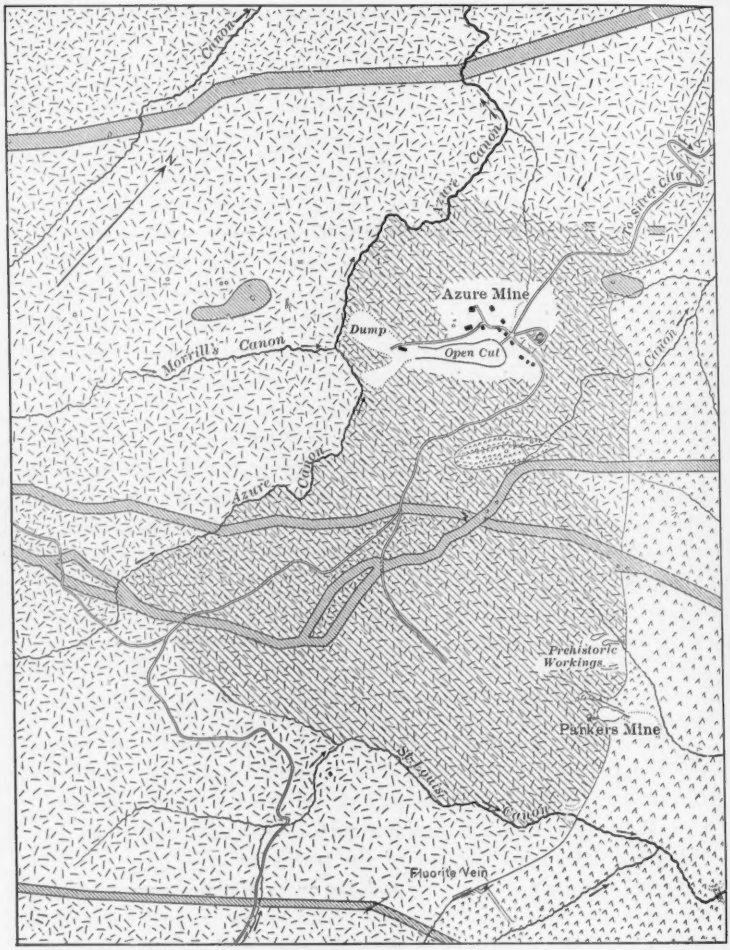

FIG. 51. Geologic map of the Burro turquoise district, New Mexico.

appearance. Under the microscope the orthoclase is clouded and all biotite has been removed or changed to chlorite. Quartz veinlets containing fluidal inclusions cut the rock in various directions. Of the accessory minerals, apatite and zircon are common. At one place titanite occurs in wedge-shaped crystals of yellowish to brown color up to one-half inch long. Aplite and pegmatite were noted in Dead Man's Cañon.

Veins.—Turquoise is found in a strong vein or fissured zone

FIG. 52. Intersecting fissures in Azure mine.

which strikes N. 47° E., and dips S. at 45°.[1] It has a well-defined foot and hanging wall, both of which show polished faces and evidence of movement. The material between the walls, however, is not entirely vein filling, but rather a much altered zone in the granite, containing soft spots and streaks of nearly pure kaolin, also secondary vein quartz resulting from the decomposition of the feldspar. All ferromagnesian minerals

[1] The magnetic variation is 12° 20′ east on the Azure Mining Company's claims. Directions given here and on the map are magnetic readings.

FIG. 53. Open cut of Azure mine.

have disappeared. The turquoise occurs only between the two well-defined walls, and for convenience this zone will be spoken of as a vein, though strictly speaking it is a sheared and altered zone containing vein material in places.

Two sets of fissures, Fig. 52, cut this zone and show plainly in the less altered portions. These strike in the same direction as the vein. One set dips S. at 45°, parallel to the walls, while the other crosses the first set and dips N. at 60°–70°. This fissuring is not local, but occurs over several miles of surrounding country. It can be seen in Dead Man's Cañon over half a mile to the south.

The vein is 40 to 60 feet between walls and is developed by four levels. An open cut has been driven from the second level workings for a distance of over 600 feet. Fig. 53 gives an idea of the large amount of rock removed. The second level is 70 to 80 feet below the surface. On account of the extreme kaolinization and relative softness of the altered zone, the vein forms a marked depression along the outcrop.

The granite for some distance surrounding the vein is more or less kaolinized. The altered area extends about half a mile on the southeast to St. Louis Cañon. On the south it is practically bordered by Azure Cañon, though some altered portions occur beyond this. Northeast from the open cut it extends about 1,000 feet to the contact with the porphyry, and the granite along the contact is much kaolinized. Fig. 51 shows the altered area.

Porphyry.—The rock which has been spoken of as porphyry belongs to the mica-andesite series, and has a close affinity with dacite. It is not a surface flow and has cooled relatively slowly, though rapidly enough to have some glass in the base. It is a fine-grained, compact rock, of light color, carrying quartz, often in abundant dihexahedral crystals, from one-quarter inch to three-quarter inches in diameter, with a pyramid and prism developed on some crystals, while others are simply the double pyramid. Phenocrysts of feldspar are also present. The microscope shows the feldspar to be largely plagioclase. Biotite

Fig. 53. Open cut of Azure mine.

occurs, and has been partly altered to chlorite. A small amount of glass base is present. The accessories are apatite and zircon.

The porphyry was intruded into the granite, evidently in the form of a stock, but the exact extent was not determined. The contact is irregular, the general direction being northwest and southeast. It crosses a gulch about 800 feet northeast of the Azure camp and can be followed south past the prehistoric workings on the Calliate claim to Parker's large open cut. See Fig. 51. Thence it can be traced across St. Louis Cañon and up the east slope to the Burro Chief claim of the Burros Copper Mine. The mine lies within the porphyry. The contact with the granite is several hundred feet to the southwest; thence it crosses the ridge and continues south toward the settlement of Leopold and the Burro Mountain Copper Company.

A tongue of porphyry apparently entirely surrounded by granite is exposed at the head of a small gulch about 900 feet east of the Azure mine. Along the contact here, in the granite, are some prehistoric turquoise workings.

Turquoise stains and in some cases small quantities of the mineral may be observed at many places in the altered granite, and some staining occurs in the porphyry, but the gem has not been found in paying quantities except in the well-defined Azure vein.

Dike Rock.—Both the granite and porphyry are cut by andesite dikes. These strike northeast and in a general way are parallel to the Azure vein. Morrill's Cañon also has the same trend and is in direct line of strike with the open cut. It was evidently eroded along the lines of the strong fissuring. Up to date little turquoise has been obtained on the southwest side of Azure Cañon, though the continuation of the vein has been sought at this point.

The dike rock is gray where fresh and weathers yellowish brown. It shows large feldspar phenocrysts in a compact fine-grained groundmass. The feldspar is orthoclase in finely developed crystals with Carlsbad twinning. Zonal structure is frequent. Quartz occurs in dihexahedral crystals as in the por-

phyry and biotite can occasionally be seen. A feldspar crystal obtained from the large dike near Dead Man's Cañon measured 3 inches by 2½ inches. The combination was that of base, prism, brachypinacoid and an orthodome.

Thin sections show that aside from the phenocrysts the predominating feldspar is plagioclase. The biotite is much chloritized. There is more glass in the base than in the porphyry, but the general mineral content is the same. Apatite occurs in some quantity. The dikes and porphyry are evidently successive eruptions of the same magma. It is difficult to determine whether the rock is a mica andesite or dacite, as gradations from one to the other occur. In places the rock carries orthoclase in such quantities as to approach the rhyolites. Both the dikes and earlier andesite are porphyritic. For distinction the latter has been spoken of as *porphyry,* while the former is termed simply *dike-rock.*

Three main dikes have been traced through the Azure property and can be followed northeast and southwest on adjoining ground, in all a distance of over 1½ miles. On the southwest they cross Dead Man's Cañon. Exposures here show the dip to be nearly vertical. Northeast they can be followed into Parker's property and are lost under the Mangus Valley wash. Similar dikes from 40 to 90 feet in width cut across the sedimentary beds previously mentioned. The two dikes south of the mine are about 50 feet wide, while the dike north of the Azure vein near Morrill's camp is, in places, 90 feet or more. The dike farthest to the southeast forks at two points and again joins enclosing granite between the branches. This dike and its neighbor intersect about 1,500 feet southeast of the Azure camp. A small horizontal displacement was observed in the north dike which was not to be found on the first, indicating that the southern dike is probably the younger. The line of faulting is approximately parallel to Dead Man's Cañon and the west side of the fault moved about 30 feet to the north. A fourth andesite dike crosses St. Louis Cañon and ridge near the Burro Chief Copper Mine, having the same general trend as the others.

Some copper staining occurs at various places along the dikes, but no traces of turquoise were found.

OTHER TURQUOISE OCCURRENCES IN THE BURROS.

Turquoise occurs at three other points in the Burros and in the Cow Spring district several miles to the southeast. It is found at Parker's mine, a short distance southeast of the Azure camp. The workings are near the contact of granite and porphyry, the prehistoric workings all being in the granite. Quantities of rude stone hammers were found here. These were made of harder portions of the altered granite and in some cases this rock even contained turquoise. They are of rounded form, four to eight inches or more in diameter, and were evidently used without a handle.

Charcoal found in the excavations suggests that fire and rapid cooling may have been used in the primitive mining, the rock afterwards being broken in small pieces with the stone hammers. Turquoise of good color and quality is found at Parker's, disseminated through the altered granite.

About three-fourths of a mile southeast of Azure, near the Burro Chief Copper Mine, turquoise is found in two places, one on the summit of the ridge in the granite, and the other northeast across a small gulch in porphyry. The material is not of gem quality.

Maroney's turquoise prospect lies near the Silver City road northeast of Leopold. The granite here is kaolinized and some translucent dark blue turquoise has been found disseminated in the altered rock. This is of good quality, but limited as to quantity and size.

A few miles southeast of the Big Burros, in the Cow Spring district, is another turquoise occurrence. The conditions are of the same general character, turquoise being associated with kaolinized country rock. Some turquoise was noted here in thin seams, though of good color.

In every case the turquoise is associated with kaolin. It occurs in small quantities as nuggets, concretions and veinlets irregularly distributed in the altered country rock, but excepting on the Azure property does not occur in definite well-defined veins.

THE AZURE VEIN.

The Azure vein strikes N. 47° E. and dips S. at 45°. Turquoise of good quality was found here on the outcrop. After the organization of the Azure Mining Company in 1891, development proceeded through four adit levels driven northeast on the vein, and resulted in the production of turquoise equal if not superior in quality to the best Persian gems. In 1893, Mr. Felix Vogel, then superintendent, opened up the famous Elizabeth Pocket, which produced more high-grade turquoise than any single deposit on record. The color was mostly deep blue and the material being slightly translucent and above 6 in hardness, made ideal gems. The turquoise was found in two forms —as vein turquoise filling cracks in the altered granite and as nuggets or concretions imbedded in kaolin. Over ten kilograms of the finest material, mostly nuggets, were produced in one month.

The Elizabeth Pocket extended from the second level to the surface, a distance of 40 to 60 feet, and the same quality of turquoise was found for 150 feet or more along the vein. The distance between walls is about 40 feet.

Some good turquoise was developed on the third level and sparingly on the fourth, but here turquoise of the best quality was not plentiful and is associated with malachite and chrysocolla. It appears that an excess of copper gives the material a green color and also decreases the hardness. Whether depth is an important factor in the genesis or formation of ideal turquoise cannot be determined, but at the present time all the fine turquoise is found at depths of 100 feet or less. Possibly the formation of turquoise took place at a definite temperature and pressure, which may account for its limited vertical range.

Turquoise occurs as vein turquoise and nuggets. The vein turquoise fills cracks and fractures in the rock and is from one sixteenth up to three fourths of an inch in thickness. Most of it, however, is probably from one eighth to three eighths inches, but it has been found up to one and a half inches thick. Vein turquoise occurs with rounded edges and corners resem-

bling nugget structure. The nuggets or concretions are usually in the softer portions of the vein and along seams, entirely imbedded in kaolin. They have various shapes and sizes—reniform, botryoidal, etc., and make the finest gems.

Vein rock from near the Elizabeth Pocket showed a medium fine to coarse-grained structure, traversed by a more than usual amount of quartz in veinlets and bands up to one half inch or more wide; these are sometimes open and contain cavities lined with quartz crystals. Vein turquoise sometimes contains small quartz crystals penetrating the turquoise from the sides of the vein. Bordering these quartz bands is kaolinized feldspar. The quartz often gives way to bright blue turquoise, which partly or entirely fills the vein or occurs in isolated specks. Vein turquoise is often separated from the granite on one or both sides by quartz and also occurs in direct contact with the rock without quartz filling. Turquoise when intimately mixed with quartz is usually light blue and of even grain.

Some portions of the vein rock are less altered and occasional pink orthoclase crystals are found. In material of this character bright blue turquoise occurs. No pyrite has been observed in the vein, though a few cubical cavities partially filled with limonite occur and the rock is frequently stained brown by limonite. The vein material in places is almost entirely changed to kaolin. It is here that some of the best nuggets are found.

The character of the turquoise varies from place to place along the vein and different kinds are also found closely associated. An example of this was shown by veinlets of blue turquoise of different shades crossing each other. A light blue veinlet of turquoise, slightly greenish cast, was crossed by a blue vein. Turquoise must have been deposited at successive periods and under somewhat different conditions. Movement and fracturing occurred between the periods of deposition.

Northeast of the Elizabeth Pocket the color was a good blue for some distance, then came a point where blue and green turquoise occurred together, farther northeast the green shade predominated. This again changed to the blue with varying amounts of green.

Near the mouth of the open cut on the east or hanging wall side of vein, fissures were found in which both turquoise and copper minerals occurred. These fissures belong to the copper bearing set and dip to the northwest. The vein dips to the southeast. In the vein where the copper-bearing fissures cross it turquoise of bright blue color was found. See Fig. 54, which

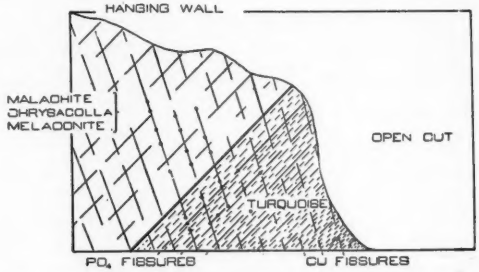

FIG. 54. Sketch showing relation of turquoise to fissures.

is a sketch showing the relations of the fissures, turquoise, and copper minerals at this point. Following the same turquoise-bearing fissures from the vein into the hanging wall and five or six feet away from the turquoise, the fissures contain malachite, chrysocolla, and black oxide of copper, in thin seams. This has passed through the vein and must have been in excess of the copper which combined to form turquoise at this point. The turquoise exists only in the vein and not in the hanging wall, showing that where the copper crossed the phosphate solutions the turquoise was formed.

The largest movement occurred on those fissures which were parallel to the vein. They are frequently found slickensided. On the copper-bearing fissures no slickensides have been observed. The geological map shows a series of copper shafts and prospects in the granite on the southwest side of Azure Cañon. These are along a copper-bearing zone parallel to the turquoise vein and on the west, or footwall, side. The chief copper minerals in these prospects are chrysocolla, malachite,

and some black oxide, chrysocolla being the most plentiful. No pyrite or other sulphides have been found in the immediate neighborhood of the turquoise vein. If such existed they have been oxidized. The footwall of the vein is colored red by hematite. From all appearances, however, pyrite was not plentiful. The only place in the entire neighborhood where it was observed fresh and unaltered was in a copper prospect on the ridge near the Burro Chief. In a shaft sunk here for copper, near an andesite dike, some earthy varieties of green and blue turquoise were found. Vein quartz taken from the shaft showed pyrite disseminated through it in fresh cubical crystals, also occasional grains of chalcopyrite. In the Burro Chief, a short distance to the east, chalcochite, malachite, azurite, and chrysocolla occur. Following the above dike northeasterly across the Burro Chief gulch is another occurrence of turquoise, which is the one described by C. H. Snow.[1] The turquoise forms a network of thin light blue veinlets in the dike, which at this point is greatly altered and shows a structure similar to diorite. The turquoise is not of gem quality. The country rock here is porphyry.

MINERALOGICAL NOTES.

Turquoise.—The specific gravity of turquoise is given as from 2.60 to 2.89. There is undoubtedly a marked difference between the hard translucent blue and soft earthy varieties. Its hardness is rated at 6 but the average turquoise is probably slightly less. Some specimens of vein turquoise are over 6 and are scratched with difficulty by a knife blade.

Turquoise breaks with conchoidal or uneven fracture. The texture varies from the fine-grained subtranslucent blue to the soft chalky quality. Radiating forms occur resembling wavellite in structure.

Almost all shades of blue and green are found: dark blue, sky blue, light blue, slate blue, bluish green, greenish blue, through all shades of green to dark green, reddish brown (pos-

[1] *Am. Jour. Sci.*, 1891, Vol. 41, pp. 511.

sibly from the separation of cupric oxide, or admixture with ferric salts), chocolate color, violet and purple. Some pieces show different shades and colors in the same specimen. Blue and green are the most common colors though the latter is not used in jewelry.

Turquoise may be evenly blue or mottled by darker spots in a mass of uniform color. The latter is spoken of as *mottled matrix*. The spots may be large or small and occasionally associated with these are irregular wavy lines of darker turquoise material. Occasionally the spots predominate, leaving little of the plain blue or green turquoise to be seen. This variety occurs in various shades of robins' egg blue. As a rule mottled vein turquoise of good color is found in hard rock.

Nuggets are usually covered with a characteristic white skin or coating, which probably consists of aluminum phosphate, perhaps mixed with some kaolin. Nuggets sometimes contain quartz grains and included vein matter; occasionally they are of good color on the outside, but contain a yellowish or whitish portion in the center, or vice versa.

Halloysite.—A mineral having many of the characteristics of turquoise, though as a rule of inferior hardness, is found closely associated with turquoise in the vein, and Clark and Diller, in their article on "Turquoise from New Mexico,"[1] mention a similar occurrence in the case of the Cerrillos turquoise, but consider it as epidote. They say in this connection:

> "One of the most important constituents of the rock, because of its very close association with turquoise, occurs in the form of bright yellow grains, in all probability epidote. It is evidently connected genetically with the turquoise for it is almost uniformly found on the border of the latter and most abundant in its neighborhood."

This describes almost exactly the material here considered.

The mineral occurs in vein form and as white or grayish nuggets. Some of this material is hard and covered with a white coating similar to the best kinds of turquoise. An open crack in one of these nuggets was lined with small crystals. They are

[1] U. S. Geol. Survey, Bull. No. 42, 1887, pp. 39–44.

entirely colorless and possess considerable luster. With a magnifying glass they are seen to be short hexagonal prisms terminated by the base. The crystals are too small for actual determination, but from mode of occurrence and crystal form suggest a phosphate, possibly apatite.

Several large nuggets were found in a seam with kaolin, on the foot wall side of the vein. One of these measuring 3½ inches by 2 inches by 2½ inches was solid and compact. It could barely be scratched with a knife, had a light olive tint and was slightly translucent. The central part of the nugget was bordered by radial fibers about one-half inch long of the same material, but softer than the center. This was the largest nugget found. Others are of olive green and grayish shades and vary from opaque to translucent, with waxy luster. The white coating is the same as on the turquoise nuggets. More commonly the mineral occurs in bright green grains, or yellowish green when fresh. It cracks on exposure to the air.

Some nuggets with the white skin coating when broken show the center to be bluish or greenish shading off to white near the border, and the reverse is also true. These are really a poor quality of turquoise and appear to be due to an excess of aluminum phosphate.

Beside the regular blue and green turquoise, local variations in color and quality occur. The following special types were noted: pale blue vein-turquoise with a network of yellowish-brown, hydrous aluminum phosphate streaks; dark-green mottled vein-turquoise passing into almost a chocolate brown; blue-green vein-turquoise bordered by quartz and thickly covered by a network of reddish-brown hematite veinlets; green mottled turquoise translucent on edges; peculiar blue-white vein turquoise containing open cracks and darker streaks, evidently cracks filled with turquoise material; turquoise of dark slate-blue color, in places almost purple, of fine, even grain, but not good for gem material; irregularly colored vein-turquoise; pale green turquoise passing to a dark purple-blue, then gradually into light blue, and this separated from light green by a dark purple band;

bright blue vein-turquoise enclosing and intimately mixed with olive green aluminum phosphate distributed throughout the turquoise in patches up to one half inch in diameter; light-blue vein-turquoise containing yellow spots of phosphate, quartz grains and darker veinlets of purple and blue parallel to the walls.

EFFECT OF KAOLINIZATION.

Where the kaolinization of the vein rock has been greatest and the rock is soft, turquoise is found mostly in nugget form. In moderately hard spots which show kaolinized fissures, both nugget and vein turquoise are found. Where kaolinization has been less complete vein turquoise alone exists.

Across the face of the open cut, some 600 feet from its mouth, are three distinct zones of kaolinization. Beginning on the east at the foot wall side of the horse is a zone 5–6 feet wide which is soft and contains little solid vein rock. It appears to have been the main zone of kaolinization and the path of the heated vapors and solutions. The boundary is sharp on the east against the horse of almost unaltered granite, and a distinct boundary with the neighboring zone (zone 2) exists on the west. Zone 2 is partly kaolinized and contains some solid vein material. Both nuggets and vein turquoise occur and it is considered good rock. This shades almost imperceptibly into zone 3, against the footwall of the vein. Zone 3 is hard rock and shows plainly the two sets of fissuring—see Fig. 52. All turquoise found here is vein turquoise. In the fissures cutting across the vein near the footwall the turquoise is frequently green and appears to contain a large percentage of copper. Higher in the vein it changes into blue. Above the horse along the hanging wall to a light blue. From this it would seem as if the copper solutions rising through the footwall gradually combined with the aluminum phosphate to form turquoise, the copper content in the higher part of the vein being less on this account. In all parts along the vein it is noticeable that light blue turquoise occurs near the hanging wall.

COMPOSITION OF TURQUOISE.

The microscopic structure of turquoise was first studied by Professor Fischer of Freiberg, and later by H. Bücking,[1] F. W. Clark and J. S. Diller,[2] and D. W. Johnson.[3]

In thin sections turquoise is pale blue to almost colorless. Under crossed nicols it shows a fibrous structure of doubly refracting particles. These, in vein turquoise, are usually at right angles to the walls, but also show a tendency to collect in small radial aggregates. In some cases the radial structure is absent. The crystal system of the mineral has not yet been determined.

Material has been collected for a detailed microscopic investigation of turquoise, and over a hundred rock sections have been prepared. These include all the chief types of turquoise, aluminum phosphate, vein material, unaltered granite, and the andesite and dike rocks of the neighborhood.

Turquoise is a hydrous phosphate of aluminum and copper. The chemical structure is complex, and has given rise to differences of opinion as to the rôle played by the bases, more especially the part taken by the copper.

The following table shows analyses of various types of turquoise, and comprises most of the data now obtainable on the subject.

The analyses have been discussed in part by Clark and Diller.[1] Also by Professor S. L. Penfield,[2] and later reviewed by D. W. Johnson.[3]

The table indicates a fairly constant composition. The water is not hydroscopic, but exists in combination. The alumina is

[1] "Mikroscopische Untersuchung des Türkis," *Zeitschr. f. Krystallog.*, Vol. II., 1878, pp. 163.

[2] *Amer. Jour. Sci.*, 3rd ser., Vol. 32, 1886, p. 211 and U. S. Geol. Survey, Bulletin No. 42, 1887, pp. 39–44.

[3] Contributions from the Geological Dept. of Columbia University," Vol. X., No. 90—*School of Mines Quarterly*, 1903.

[4] "Turquoise from New Mexico," Bull. 42 U. S. G. S., 1887, pp. 38–41.

[5] "The Chemical Composition of Turquoise," *Am. Jour. Sci.*, 4th ser., Vol. X., 1900, pp. 346–50.

[6] Geology of the Cerrillos Hills, New Mexico, *School of Mines Quarterly*, 1903, pp. 201–203.

ANALYSES OF TURQUOISE.

	1	2	3	4	5	6	7	8	9	10
H_2O	18.85	19.80	19.60	18.49	19.34	19.98	18.60	19.38	18.24	18.59
Al_2O_3	29.17	39.53	36.88	37.88	40.19	35.98	35.79	35.03	34.32	42.17
Fe_2O_3	29.57		2.40	4.07		2.99	3.52	1.44		
P_2O_5	4.04	31.96	32.86	28.63	32.86	33.21	34.42	34.18	28.29	29.43
CuO	12.57	6.30	7.51	6.56	5.27	7.80	7.67	8.57	7.41	5.10
SiO_2	4.35	1.15	0.16	4.20						
FeO	1.61				2.21				0.91	4.50
CaO		0.13	0.38	undet.					7.93	
MnO					0.36					
Insol								0.93	2.73	
Total	100.16	98.87	99.79	99.83	100.23	99.96	100.00	99.53	99.83	100.00
Sp. Gr.			2.805	2.426–2.651[1]	2.75	2.798–2.815	2.89	2.79		

1. Cerrillos turquoise, Dr. Oscar Leow, 1875.
2. Cerrillos turquoise, bright blue faintly translucent in thin splinters, Professor Clarke, U. S. G. S.
3. Cerrillos turquoise, pale blue greenish cast, opaque and earthy, Clark and Diller, U. S. G. S.
4. Cerrillos turquoise, dark green, opaque, Blake.
5. Persian turquoise, bright blue, Professor A. H. Church.
6. Fresno County Cal., G. E. Moore,—Pseudomorph after apatite.
7. Karalinsk in Kirghiz Steppes, Nikolaieff.
8. Lincoln County, Nevada, Professor S. L. Penfield.
9. Burro Mountains,—M. Carnot (Mineral Industry 1896–1897).
10. Persia, M. Carnot.

replaced in some cases by small amounts of ferric oxide and is relatively constant, as is the phosphoric acid. Cupric oxide varies from 4 to 8 per cent., and in bright blue turquoise is about 5 or 6 per cent. Ferrous oxide was determined in several of the analyses, and M. Carnot, from his analysis of the Burro Mountain turquoise (No. 9 in the table), emphasizes the fact that all iron occurs in the ferrous form. Analyses Nos. 2–5, both of bright blue turquoise, show a marked similarity. In No. 1, Dr. Leow separated the turquoise from the matrix, and says the large percentage of silica occurred in the gem itself. Analyses Nos. 2–3–4 are discussed by Clark and Diller, who consider the silica in No. 4 to be part of the gem, but in No. 2 to be due to mechanically mixed rock with the turquoise. The latter analysis is not complete owing to lack of material. Under the micro-

[1] Sp. gr. for similar specimens.

scope small grains of quartz are often seen entirely surrounded by turquoise, and it seems probable all of the silica in the analysis came from this source.

Clark and Diller, from the analyses Nos. 2, 3, 5, 6, 7 (omitting the analysis of the dark green variety, No. 4), calculate the atomic equivalents for the combined bases, phosphoric acid, and water, and find for these analyses that the atomic ratios are nearly constant. The base stands to the acid in the ratio of a little over 2 to 1, and the water is present in the proportion of a little under 5 molecules to one of phosphoric acid. By calculating the amount of phosphoric acid necessary to satisfy the alumina, and figuring that this phosphate requires 5 molecules of water, they obtain the formula

$$2Al_2O_3,\quad P_2O_5,\quad 5H_2O.$$

The copper, acid, and water remaining is then represented by

$$2CuO,\quad P_2O_5,\quad .4H_2O,$$

and the turquoise is regarded as a variable mixture of these two salts.

They consider the hydrous copper phosphate as the coloring material, but say it exists merely as an impurity. From the analysis of the dark green turquoise (No. 4) Clark and Diller refer the green color to admixture of salts of iron. They say, "It is exceedingly probable that the purity of tint in gem turquoise is due to the copper salt alone and that degradations of the color towards green are ascribable to a mixture of salts of iron. It is noteworthy that of three turquoises analyzed, the bluest contains the lowest percentage of copper. This could hardly be the case were not the colors of the other samples modified by some impurities, and compounds of iron would naturally produce an effect in the observed direction." It does not seem necessary that green colors should be due to an excess of iron alone. Blue turquoise of poor quality often turns green by a chemical change in the copper salt.

Professor Penfield concludes from his own and other analyses that copper and small quantities of iron are necessary constitu-

ents of turquoise, and not present merely as impurities. This view is substantiated by the physical character of turquoise of various types, and by its closely associated mineral the hydrous aluminum phosphate. This appears to be turquoise without the coloring matter. When copper is present and colors or partly colors this material, it very much increases the hardness. This can be seen in the same specimen where turquoise is surrounded or coated by the phosphate, and in vein phosphate and turquoise which show gradations from one to the other. From the physical properties of turquoise it appears that the coloring material, the hydrous copper phosphate, is not present as an impurity, but is combined with the hydrous aluminum phosphate, probably in variable proportions, producing turquoise of different qualities and colors.

For a definite kind of turquoise, however, as in the best quality of bright blue color, the component phosphates seem to be combined in definite proportions. This is shown by analyses from widely different localities which agree so closely in the essential components as to leave little chance for any part of the material being included as a mechanical mixture or existing as an impurity. The copper must be present in molecular combination.

Several forms of turquoise and varieties of the doubtful mineral were obtained for analysis.

Through the kindness of Professor J. F. Kemp, of Columbia University, it has been possible to have an analysis made of the bright yellowish green mineral which nearly always accompanies turquoise. The writer is also indebted to Professor Kemp for his interest and kindly criticism. The green mineral was thought to be a phosphate, but differs from the other forms in being much softer. A nugget of this material when fresh from the mine is about the consistency of a hard candle and contains no grit.

The bright green mineral is difficult to obtain clean and contains some adhering particles of vein rock—largely silica and kaolin. It was taken fresh from the mine and kept bottled and corked. An analysis of this material was made by M. K. Adams,

of Columbia University, to whom the writer is much indebted. It gave the following results:

ANALYSIS OF GREEN MINERAL.

SiO_2	42.59		
Al_2O_3	19.70		
Fe_2O_3	2.46		
FeO	.06		
MgO	.63		
CaO	2.71		
Na_2O	.53		
K_2O	.20		
H_2O	25.36	below 108°	17.86
		above 108°	7.50
P_2O_5	.89		
MnO	.00		
TiO_2	.11		
Cu (metallic)	3.89		
	99.13		

It is difficult to interpret this analysis which is not that of a hydrated phosphate. It is rather too high in silica and too low in alumina for copper-stained kaolin, beside which it contains an unduly large percentage of water—nearly twice that of kaolin. The percentages of silica and water correspond closely to some analysis of halloysite, a hydrous aluminum silicate, which occurs in veins as a secondary product. It has a waxy luster, is often translucent, and is found in granite, being derived from the decomposition of feldspar. Considering only the silica alumina and water, the analysis, though lower in alumina than most analyses given for halloysite, resembles the following one by Zellner[1] from Striegau in Silesia:

ANALYSIS OF HALLOYSITE.

SiO_2	42.00
Al_2O_3	20.12
Fe_2O_3	8.53
MgO	2.01
CaO	2.81
K_2O	.50
H_2O	24.00
	99.97

The iron is somewhat lower than in this analysis. From its nearly uniform appearance in different parts of the vein it would

[1] *Jahrb. Min.*, 1835, 467.

seem that the material has a definite composition and is closely related to halloysite. The copper, if not essential, may be due to admixed silicate. On the other hand the coloring is uniform with no sign of copper staining, and we may have a mineral which is a hydrous silicate of alumina and copper, instead of turquoise, the hydrous phosphate of these two metals. The writer is inclined to take the latter view, but at the present time it is still an open question. He hopes to be able to give analyses of other forms of turquoise, and phosphates in the future.

GENESIS OF TURQUOISE.

Concerning the genesis of turquoise a number of hypotheses have been advanced. The occurrences in different localities each seem to be under somewhat different conditions. Most agree in this, however, that the turquoise is closely associated with decomposed feldspathic rocks in which the feldspar is considerably kaolinized. Also where turquoise exists more or less copper occurs in the neighborhood.

At Cerrillos the country rock is an augite andesite. Professor Silliman[1] believed the alteration of this to be due to the escape of heated water vapor and perhaps other vapors and gases which destroyed the original crystalline structure of the rock, and produced new chemical compounds. Of these turquoise was the most important. The feldspar was kaolinized and furnished the alumina, while apatite which existed in the country rock contributed the phosphoric acid. The copper diffused in the veins of this region gave the turquoise its color.

Clark and Diller, also speaking of the Cerrillos turquoise, regarded it as having replaced veins of apatite. They say that the small size of the veins and their limited distribution show the turquoise to be of local origin, and probably to have replaced some other mineral; also that the perpendicular arrangement of the fibers in rock section indicate that the mineral may have been derived from the alteration of another substance with which the vein was formerly filled. This substance was presumably a

[1] "Notes on the Turquoise of New Mexico," *Am. Jour. Sci.*, July, 1881, pp. 67–71.

phosphate and turquoise has been known to form pseudomorphs after apatite. The coloring was due to copper which exists as an impurity.

Johnson in his thesis on the Geology of the Cerrillos Hills, New Mexico, discusses the origin of the turquoise in some detail. He says: " There is every reason to believe that the crushed and sheared zones in the andesite formed passage ways for the active agents which effected decomposition." Tourmaline also occurs in the decomposed country rock and suggests the action of escaping vapors, gases or waters. The kaolin from the feldspar furnished the alumina, and the phosphoric acid undoubtedly came from the apatite. The latter was found in thin sections in the unaltered portions of the rock, but had disappeared in the neighborhood of the turquoise. Sections under the microscope suggested that the turquoise formed in the crevices directly as one of the various alteration products of the minerals constituting the country rock. The copper was supplied by the solutions which gave rise to the copper-bearing ores of the region. Johnson finds that " the intimate association of fluorite with the turquoise is very suggestive. The relations and appearance are such as we should expect if the turquoise formed first leaving the fluorine of the apatite to make fluorite which later formed about the turquoise. The proportion of fluorite to turquoise is also suggestive of the proportion of fluorine to phosphoric acid in apatite." Pyrite, limonite, and quartz are the other accompanying minerals. The pyrite is occasionally found imbedded in masses of bright blue turquoise.

Regarding the genesis of the Burro Mountain turquoise the following points may be emphasized. The country rock in the neighborhood is granite. Into this was intruded andesite porphyry, and later andesite dikes. The turquoise occurs through an altered area in the granite. The intrusion of the dikes undoubtedly played an important part in the alteration of this area, though the fissuring may have been due to other causes. It seems likely that the alteration was produced at least in part by pneumatolytic action. The dikes themselves are extensively

altered. Near Morrill's camp large orthoclase crystals while retaining their outward form are almost completely changed to kaolin. That the kaolinization began along cracks and fissures is clearly illustrated in a specimen of granite, from near Dead Man's Cañon, containing a mass of pink orthoclase. Through this ran a small quartz filled vein, bordering on which the orthoclase was white and kaolinized, while a short distance from the veinlet it was fresh and unaltered.

The strike of the Azure vein and the lines of fracturing and greatest kaolinization are in a general way parallel to the dikes. Hot solutions or water vapor which may have ascended through the crushed granite and along the fissures parallel to the dikes were probably the active agents in producing the extensive kaolinization.

The Azure vein dips toward the center of the altered area and was evidently one of the main avenues of the escaping vapors. Nearly all biotite disappeared and the orthoclase changed more or less completely to kaolin. The iron in the vein was leached to the footwall which is heavily iron-stained. Silica was set free during the operation and may have also been brought in by the solutions rising along the vein. It was redeposited in cracks and fractures with the turquoise. The phosphoric acid was probably derived from the apatite of the granite. Whether it combined with the alumina of the feldspar in depth or where the turquoise was deposited is an open question. It appears that the aluminum phosphate rose along the vein in fissures parallel to the walls, for in these fissures it is most commonly found. The copper solutions on the other hand rose along another set of fissures parallel to the vein, but dipping northwest at about 60° and crossing the aluminum phosphate-bearing fissures. The solutions must have been contemporaneous and after kaolinization was well advanced. Where they intermingled turquoise was found. The gem is found along both the copper-bearing and aluminum phosphate fissures. On the footwall side of the vein, along the copper fissures, the turquoise in places is greenish, probably from an excess of copper. In the other fissures

the aluminum phosphate is sometimes in excess. Good quality of turquoise occurs along both sets of fissures and between them throughout the vein.

As a rule little valuable turquoise comes in the porphyry, but it occurs mostly in the granite not far from the contact. The influence of the porphyry, however, in the formation of the turquoise must not be overlooked. It was intruded into the granite with crushing and fracturing of the latter near the contact. This formed a more ready passage way for the solutions and vapors which accompanied the intrusion of the dikes and consequently the granite along this zone was most kaolinized and altered.

Fluorite was mentioned in discussing the genesis of the Cerrillos turquoise. It is present also in the Burros. About 900 feet north of the Burro Chief on the west slope of the Burro Chief gulch is a fluorite vein which can be traced some 200 feet on the surface. The strike is N. 20° E., and the dip 76° S. E. The fluorite is on the contact of the granite and porphyry, and the vein is from one to two feet wide. Both walls are altered and contain cavities often several inches in diameter. The prevailing color of the fluorite is light green, but other shades also occur. It occasionally contains cavities lined with the somewhat rare form of pinkish octahedral crystals. Calcite is found in masses several feet thick along the hanging wall.

The deposit was developed by an inclined shaft sunk on the vein connecting with a tunnel from the gulch. Some of the spar was shipped for fluxing purposes.

An examination of a number of rock sections failed to show any isotropic mineral present in the turquoise vein. The fluorite appears to have collected in the one vein above mentioned and deposited on the granite-porphyry contact, which evidently formed a ready passage way for the solutions. This deposit is approximately at the same level as the turquoise in the Azure vein, and in depth the fluorite narrows and thins out, while copper minerals, malachite and chrysocolla, are more in evidence.

An hypothesis is a tool, which may be used till a better one

is found. The view that turquoise was formed by solutions rising along two sets of fissures, one of which brought the phosphoric acid and caused the kaolinization, and the other coming from the footwall of the vein bringing the copper component, led to the development of turquoise which had been passed by for years. Near the mouth of the open cut the footwall of the Azure vein slickensided and iron-stained, and looks to all appearances the same as the remainder of the footwall. Close examination, however, showed it to be more kaolinized. If the solutions, gases, etc., causing kaolinization brought the hydrous aluminum phosphate and the copper came in through the footwall there was every reason to expect turquoise would be formed here. This proved to be the case. The first round of shots which was put in this ground gave on the clean up three buckets full of bright blue Elizabeth quality turquoise. The true footwall of the vein was found some fifteen or twenty feet back of what had formerly appeared to be the footwall. This ground furnished desirable material.

Movement occurred after the turquoise was formed and the gem was deposited at successive periods and possibly under different conditions. This is shown by faulted veinlets of turquoise and by veinlets of different shades of blue crossing each other, also by cracks in the turquoise filled by a later generation of turquoise of darker color.

TREATMENT OF MATERIAL.

The turquoise as it comes from the mine passes through a sorting house and is shipped in 150-pound cases. The best quality is sent in sealed cans.

Turquoise is usually cut *en cabochon,* or elliptical with a low convex surface. It is also cut *marquis,* which is pointed at both ends. The most salable size is from 5 to 10 millimeters longest diameter, and the standard shape is oval and of medium height. A stone of this form 5 mm. long will weigh about ⅜ of a carat; one 10 mm. longest diameter from 2 to 2½ carats. The material is cut from 2 mm. up to 25 mm. in size, often

larger. Turquoise is sold by the carat, and ranges in price from $6 to $25 and higher, $15 a carat being perhaps an average price for turquoise of good color and quality.

Mottled turquoise known to the trade as "mottled matrix" and also the regular matrix, *i. e.*, turquoise and enclosing rock, are popular and bring various prices.

The Burro Mountains at the present time produce most of the turquoise mined in the United States. It is said to equal, if not excel, the gems from the celebrated Persian mines at Abu Riah and Nishapur. The demand exceeds the supply.

The following references to the literature may be of use to any one interested in the subject:

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"Observations on the Geol. of the Rocky Mountain Chain, in the Vicinity of Santa Fe, New Mexico." W. P. Blake, *Proceedings A. A. A. Sci.*, 1859, pp. 314–319. "Observations on the Mineral Resources of the Rocky Mountain Chain near Santa Fe, New Mexico." *Proceedings Boston Soc. Nat. History*, 1859, pp. 64–70.

"Notes on the Turquoise of New Mexico." Prof. Benj. Silliman, *Am. Jour. Sci.*, July, 1881, pp. 67–71.

"Turquoise from New Mexico," Bull. 42, U. S. G. S., pp. 39–44. *Am. Jour. Sci.*, Vol. XXXII., 1886, pp. 221, F. W. Clark and J. S. Diller.

"The Chemical Composition of Turquoise." Prof. S. L. Penfield, *Am. Jour. Sci.*, Vol. X., 1900, pp. 346–350.

"Report of Chief of U. S. Engineers," 1875, part ii., pp. 1027, Dr. Oscar Loew.

"Mineral Resources of the United States," 1891, pp. 544.

"Turquoise in Southwestern New Mexico." C. H. Snow, *Am. Jour. Sci.*, 1891, pp. 511, vol. 41.

"New Mexico Mines and Minerals," 1904. F. A. Jones, pp. 267.

"Geology of the Cerrillos Hills, N. M." D. W. Johnson. *School of Mines Quarterly*, 1903.

OCCURRENCE OF RUTILE IN VIRGINIA.

THOMAS LEONARD WATSON.

INTRODUCTION.

Knowledge of the occurrence of rutile in Virginia goes back many years, but reliable information of its occurrence in commercial quantity is of recent date. Prior to the opening of rutile deposits in Nelson County, Virginia, in 1902, the small domestic demand for the mineral was supplied from Chester County, Pennsylvania.

During the summer of 1906, I carefully studied the occurrence of rutile in the Virginia area, and made an extensive collection of the rutile-bearing and other associated rocks for laboratory investigation. The results of the field and laboratory study are here briefly set forth.

PREVIOUS WORK.

In 1885, Robert Robertson[1] published a brief note on the blue quartz from Nelson County, Virginia, in which the following statement was made of the presence of rutile in the feldspar-quartz rock: "It is to be noted that this belt of granulithic rocks and the accompanying gneiss frequently show crystalline masses of rutile on the surface, which have weathered out on decomposition."

The only published account of the Virginia rutile deposit known to me is that by Dr. George P. Merrill[2] in a paper presented before the Geological Society of Washington in 1902, which appeared in full in the *Engineering and Mining Journal* and in abstract in *Science* of the same year.

[1] Robertson, R., "An Examination of Blue Quartz from Nelson County, Virginia," "The Virginias," 1885, Vol. VI., pp. 2–3.

[2] Merrill, G. P., "Rutile Mining in Virginia," *Eng. and Mag. Journ.*, 1902, Vol. 78, p. 351; *Science* (n. s.), 1902, Vol. XV., p. 389.

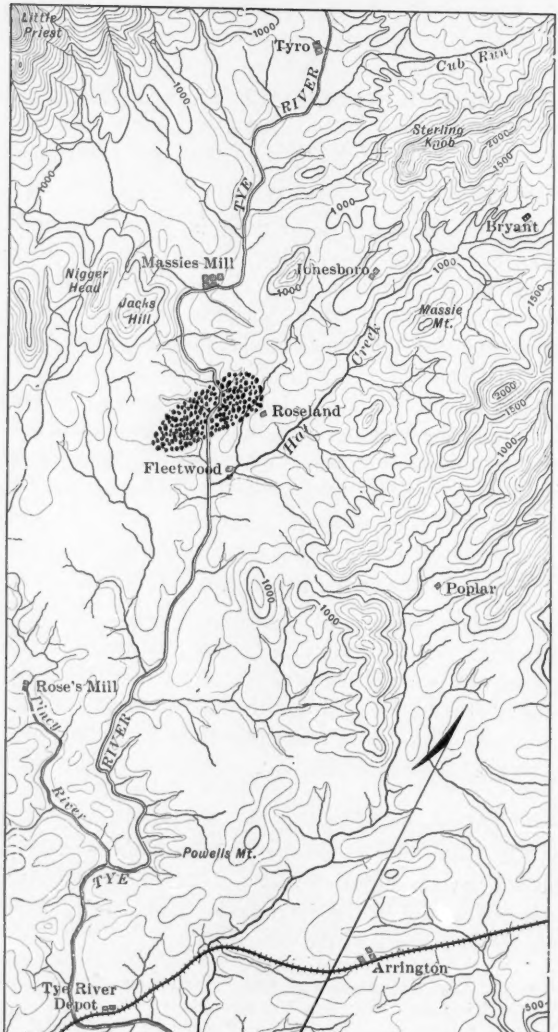

FIG. 55. Map showing location of rutile area in Nelson County, Va. Dotted area is rutile-bearing rock. Topography from U. S. Geological Survey. Scale 125000. Contour interval 100 feet.

GEOLOGY OF THE AREA.

Position and Topography.—The only locality in Virginia, and indeed in the southeast Atlantic states, where rutile has been mined, is near Roseland, Nelson county, Virginia, about seven miles slightly north of west from Arrington, a station on the Southern Railway. As indicated on the accompanying map, Fig. —, the area lies partly on both sides of Tye river, near Roseland post-office, and is owned and operated by the American Rutile Company. The entire extent of the area is yet unknown, but it comprises at least several hundred acres on both sides of the river.

The area is in the western portion of the crystalline region of Virginia, within the foot-hills of the Blue Ridge. It has moderate relief, averaging about 700 feet above mean tide level. The map, Fig. 55, shows that the surrounding country immediately to the north, east and west rises with a hilly topography to elevations of 1,000, 1,500 and 2,000 feet, respectively, above sea level.

Composition and Structure of the Surrounding Rocks.—The country rock is a pronounced foliated gneiss of variable composition. A traverse made between Arrington and Roseland showed, at a distance of about four miles west of Arrington, the principal rock to be a thinly foliated biotite gneiss of dark gray color. Biotite is a prominent constituent and the quartz is light or nearly white in color and fine granular. About two miles southwest of Roseland the rock is a biotite gneiss of thicker foliation and coarser texture than the gneiss described above between Arrington and Roseland. It contains abundant disseminated graphite which is uniformly distributed in the hand specimen. The quartz is in large grains and much of it has a marked bluish color. Feldspar is an important constituent and, to a large extent, occurs in good-sized cleavable individuals. The origin of these gneisses is yet in doubt, although there is some evidence suggesting their derivation from an original igneous rock of acid composition. Rutile is not apparent in the rock of either of the above localities.

FIG. 55. Map showing location of rutile area in Nelson County, Va. Dotted area is rutile-bearing rock. Topography from U. S. Geological Survey. Scale $\frac{1}{125000}$. Contour interval 100 feet.

Immediately adjacent to the rutile-bearing area on the southeast and the northwest is a gneiss of similar composition to the rutile-bearing rock, but which differs from the latter in more pronounced foliation, in finer texture, and in the presence of only occasional rutile grains. It differs from the gneisses described above in the general absence of biotite, the prevailingly blue color of the quartz, and in the presence of occasional rutile. It is composed essentially of deep blue quartz and light-colored feldspar with, in much smaller amount, an altered ferromagnesian silicate mineral, probably hornblende. The blue quartzes are mashed and greatly elongated in the direction parallel to the foliation and are extensively fractured across at the right angle direction. Feldspar is usually fine-granular, though larger cleavable grains occur. Every specimen of this rock examined showed the presence of occasional grains and crystals of rutile, mostly in association with the feldspar, occasionally with the quartz, and rarely occupying positions along the contact of the quartz and feldspar. Like the quartz, the rutile grains show fractures in some cases, which indicate the existence of rutile in the rock prior to the period of deformation which produced the gneissic structure. Indeed no evidence has yet been found against the supposition that it is an original or primary constituent of the rock.

The blue quartz-feldspar gneiss was traced to and beyond Bryant, a distance of nearly five miles slightly west of north from Roseland. The rock in this locality is somewhat more coarsely crystalline and, in places, contains more of the ferromagnesian mineral than the facies on the southeast of Roseland. Although as conspicuously foliated as the latter, the foliation is less regular. In both localities feldspar is the dominant constituent, though occasionally quartz may be locally more abundant. Like the feldspar and quartz, the altered ferromagnesian mineral of the rock around Bryant frequently contains visible grains of rutile.

Between Roseland and Bryant the gneiss is cut by numerous pegmatite dikes of large and small size. These are usually

deeply decayed and rutile, if present, has not been noted in them. The gneisses are also traversed by a few dikes of diabase and gabbro which will be again referred to.

The Rutile-bearing Rock.[1]—This is a coarsely crystalline acid rock of granitic composition, composed essentially of white feldspar and blue quartz with, in places, altered masses of hornblende. The ratio of these minerals is variable, feldspar being at all times the most abundant mineral. Quartz forms at times a considerable component of the rock, at others, little or none is present. In size it varies from grains of almost microscopic dimensions up to masses many inches across. Doctor Merrill states that at one of the openings being worked in 1902, quartz predominated over the other constituents, and masses of several tons weight were procured.[2] Hornblende has very irregular distribution, and from most of the rock exposed in the mine openings it is entirely lacking. Where found it forms large cleavable masses considerably altered.

The textural relations of the quartz and feldspar to each other, and of the hornblende when present, are similar to those of a coarse pegmatitic granite. In the more feldspathic portions of the rock frequent interlocking, small irregular, quartz grains are distributed. When present in large masses the intercrystallization of the quartz with feldspar appears, on casual examination, to be somewhat doubtful, as angularity and interlocking sutures give way more to rounded, somewhat elongated outlines and contacts. In such cases it seems probable that this can be accounted for in part, at least, by dynamic action, for evidence of pressure is strongly manifested in the rock both in hand specimens and in thin sections under the microscope. The feldspars are frequently granulated and the quartz is invariably much

[1] The rocks are prevailingly mantled with a variable depth of residual decay and exposures are somewhat rare. This fact together with that of lack of time rendered it impossible for me to define even approximately the boundaries between the different rocks of the area. Because of lack of exposures I am in doubt as to the exact relations obtaining between the rutile-bearing rocks and the gneiss of similar composition adjacent thereto on the southeast and the northwest.

[2] Merrill, G. P., *op. cit.*

fractured, the fractures not infrequently being closely spaced and parallel. Optical disturbance of the quartz is strongly marked in every thin section studied under the microscope. Although pressure effects are plainly manifested in the rock, it is not foliated or banded.

Inclusions of each of the minerals in the others occur, usually with more or less irregular and interlocking boundaries. The massive crystalline character and mineral composition of the rock, the size of the area over which it is found, and the structural and textural relations of the essential minerals to each

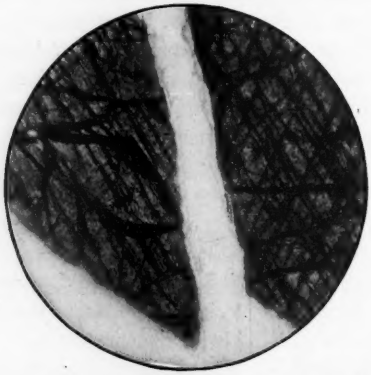

FIG. 56. Photomicrograph showing the sharp and angular outline of the rutile (dark) against the rock minerals (white). Cleavage and irregular fracture are shown in the rutile. The white is chiefly altered fibrous hornblende. × 40. Ordinary light.

other, as shown both megascopically and microscopically, indicate almost conclusively a rock of igneous origin.

Microscopical Characters.[1]—Microscopic study of a large number of thin sections of the rutile-bearing rock shows practically no variation in mineral composition which, as well as the textural relations of the minerals, is characteristic of granite.

[1] I am indebted to the U. S. National Museum, Washington, D. C., for the loan of thin sections cut from specimens of the rutile-bearing rock collected and studied by Doctor George P. Merrill, for comparative study with those from specimens of the same rock collected and studied by me.

Feldspar is the dominant mineral. Both orthoclase and plagioclase are present in quantity and are invariably altered, chiefly to sericite and kaolin. Extinction angles measured against the twinning lamellæ of the plagioclase gave an average of 22°, which corresponds to the sodic plagioclase, albite. Plagioclase in stout tabular form is of frequent occurrence, the lamellæ of which are often considerably bent and curved, and, in cases, broken across from pressure effects. Granulation and peripheral shattering, and fractures, are strongly marked. Micro-

FIG. 57. Photomicrograph showing the relations of rutile (dark) to plagioclase (white). The three white lines in the rutile on the left are fractures along which alteration has progressed. ×40. Ordinary light.

perthite is rather abundant, and several granophyric intergrowths of feldspar and quartz were noted.

Quartz, apart from its prevailing blue color in hand specimens of the rock and the great abundance of closely crowded acicular rutile inclusions in thin sections, presents no unusual features. Similar effects of pressure are shown in the quartz as in the feldspar—granulation, fracturing, and undulous extinction being the most marked.

The dark silicate mineral present, identified as hornblende, is in nearly every case much altered and is usually frayed-out about

the margins. It occurs as large irregular masses with good cleavage in one direction, and shows the effects of dynamic action in bent and curved fibers, and in fractures crossing the fibers. Of the large number of thin sections examined only a single piece of the unaltered mineral was noted. This showed the cleavages and the cleavage angle of hornblende. A few shreds of biotite were noted in one of the sections. Besides the minerals mentioned above and the ore (rutile), there is a sparse development of the usual accessory minerals common to granites.

FIG. 58. Photomicrograph showing relations of rutile (dark) to the blue opalescent quartz (white). The narrow but sharp dull gray to white altered zone which invariably rims the rutile is only faintly shown in Figs. 56 and 57. ×40. Ordinary light.

Dikes.—Two kinds of intersecting dikes of unlike composition cut the prevalent rocks of the area, namely, (1) pegmatites of granitic composition, and (2) dikes of basic igneous rocks. The first of these are quite numerous between Roseland and Bryant, and so far as they were studied they present no unusual features.

The dikes of basic igneous material are less numerous than the pegmatites. They include diabase and gabbro. Good exposures of the gabbro are found on the roadside just above Roseland and at several points to the northwest. A thin section of

the rock shows the essential minerals pyroxene and plagioclase feldspar, with considerable accessory orthoclase. A noteworthy feature of the gabbro in hand specimens and in thin sections is the large amount of ilmenite in the form of grains and crystals distributed through the rock. The ilmenite is about equally associated with the pyroxene and the feldspars. The rock is entirely massive and shows no pressure effects under the microscope.

THE RUTILE ORE.

Character and Occurrence.—The ore comprises rutile in crystalline grains and granules and in crystals of remarkable purity.

FIG. 59. Photomicrograph showing relations of the rutile (dark) with sharp irregular and angular outline to crushed medium granular mosaic of feldspar and quartz (white), chiefly plagioclase. ×40. Ordinary light.

Its physical properties are distinctively marked and the grains and crystals are always easy of identification. In places the rutile is associated with more or less ilmenite, which, when present, gives some trouble because of its difficult separation from the rutile in the present milling practice. The rutile grains vary in size from very minute granules, almost microscopic in dimensions, up to granular masses measuring nearly an inch across.

In color it is usually red to reddish brown, and has good cleavage. Prismatic crystals are not uncommon.

The rutile is irregularly distributed through the rock from sparsely disseminated grains to aggregations which make up 30 per cent. or more of the entire rock mass. The probable average is about 10 per cent. of rutile. The rutile occurs similarly in each of the three rock-forming minerals, feldspar, quartz, and hornblende. It is disseminated at times with considerable uniformity throughout the feldspathic portions of the rock. So far as mining operations extend, the rutile associated with the more feldspathic portions of the rock is generally free from ilmenite or other iron-bearing minerals, but that associated with the quartz masses is more likely to be mixed with ilmenite. When present ilmenite has a similar mode of occurrence to rutile, with which it is intimately associated. The rock is apparently remarkably free from other metallic minerals.

Specimens of nearly white transparent quartz, penetrated by large prismatic crystals of rutile of reddish-brown color, with strong vertical striations, have been collected in the same county, but beyond the probable limits of the quartz-feldspar area here described.

Microscopical Characters.—Microscopic study of a large number of thin sections shows the rutile in grains and crystals in irregular disseminations through the other rock-forming minerals, but not infrequently the rutile grains are formed in contact positions between the individual feldspar grains or between the feldspar and quartz grains, penetrating both minerals. Both angular, penetrating or interlocking boundaries, and more rounded non-interlocking boundaries occur between the rutile grains and the inclosing rock minerals.

Cleavage is well developed in the rutile and the individual grains and crystals are invariably partially or wholly rimmed by leucoxene in zones of variable widths. This alteration product has also formed along the fracture lines which often penetrate and cross the rutile grains.

Particular emphasis should be given the fact that the rutile

grains are not formed along the fracture lines, cleavage or twinning planes, of the rock minerals, but they are irregularly disseminated through the substance of the enclosing mineral, much after the fashion of primary metallic oxides or ores in igneous rocks. Frequently the fractures which penetrate the enclosing rock-forming mineral also cross the included rutile grains. These relations strongly indicate primary crystallization of the rutile with the associated rock-forming minerals, while there is no evidence for regarding the rutile to be of secondary or subsequent origin.

The microscopical characters of the rutile described above are shown in Figs. 56, 57, 58 and 59, which are from microphotographs of thin sections.

CONCLUSIONS.

The more important points established in the study of the Virginia rutile area as outlined above may be summarized as follows:

1. The country rock of the Virginia rutile area is a strongly foliated gneiss of somewhat variable composition; that immediately adjacent to the rutile-bearing rock being of the same mineral composition as the latter, and like it, containing occasional rutile grains. Blue quartz is common alike to the adjacent gneiss and to the rutile-bearing rock.

2. The gneiss adjacent to the rutile-bearing rock is of granitic composition. The component minerals bear marked effects of pressure-metamorphism, and the rock was probably derived from an original igneous one. The country rock is traversed by numerous pegmatites of acid composition, and by occasional dikes of diabase and gabbro. The last is entirely massive and contains abundant ilmenite grains.

3. Like the gneiss immediately in contact with it on the southeast and northwest, the rutile-bearing rock is of granitic composition, and is regarded as of igneous origin. It is generally more coarsely crystalline than the gneiss and is entirely massive, although evidence of dynamic metamorphism is pronounced in hand specimens and in thin sections of the rock. Its texture,

composition and the distribution of the essential minerals, feldspar and quartz are features which more closely ally the rock with pegmatites than with normal granites. The rock is remarkably free from metallic minerals.

4. Rutile, in grains of variable size and in crystals of remarkable purity, varies in quantity in the rock from scant disseminations up to 30 per cent. and more of the total rock mass, with a probable average of 10 per cent. It is disseminated through each of the three rock-forming minerals, feldspar, quartz, and hornblende. From mode of occurrence and textural relations of the rutile to the rock-forming minerals, as shown both by megascopic and microscopic study, the rutile is believed to be a primary constituent. The only metallic associate is ilmenite, which is more common in the quartzose parts of the rock than in the feldspathic facies, but is never present in large amount.

GEOLOGICAL LABORATORY,
VIRGINIA POLYTECHNIC INSTITUTE,
June 15, 1907.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

The Oxidation of Pyrite.

Sir:—The account, in your May number, by Mr. A. N. Winchell of the results of his experiments upon the oxidation of pyrite, contains the following statement: "The conditions . . . favored a much more rapid oxidation than would probably occur in nature." This statement is so misleading as to call for comment. In the first place, Mr. Winchell used distilled water for his experiment, although it is generally agreed that it is the presence of small quantities of dissolved salts that gives to the waters of the earth's crust their power to attack the minerals there present. It is not remarkable that distilled water fails to attack pyrite, and it is certainly not true that in this respect that "the conditions favored a more rapid oxidation than would take place in nature." Nor does Mr. Winchell's experiment completely prove that pure water and oxygen alone have little action upon pyrite—for, by placing the pyrite upon the aluminium gauze, he, in all probability, practically constructed a galvanic couple, thereby concentrating all the solvent action of the liquid upon the aluminium. Finally, a most important phase of the question Mr. Winchell entirely ignores, namely the physical constitution of the pyrite. It seems quite clear that a porous, non-compact variety should be much more readily oxidized than a compact variety, and the evidence of the ore deposits seems to bear this out.

Thomas T. Read.

Colorado Springs, Colo.

HOW SHOULD FAULTS BE NAMED AND CLASSIFIED?

Sir:—The interesting discussion which has been carried on recently through the medium of your journal has developed very clearly that the complicated phenomena of faulting do not lend themselves readily to a simple classification. Among other things it has been explained how normal and reversed faulting may take place simultaneously and how faulting due to compression may be erroneously interpreted as normal by neglecting the horizontal component of the fault movement. Emphasis has been laid upon the fundamental difference between faulting caused by igneous intrusion and super-elevation, and that due to compression.

I think that all will admit that the difficulties of the subject impede the adoption of a satisfactory classification, but were the subject simplicity itself, I do not believe that it can be mastered as long as we think of faulting in two dimensions instead of three. A line is a rather narrow representation of a fault plane; and while we may agree with Spurr that the movement may be in any direction on the fault plane, any direction becomes either up or down just so long as the plane is represented either graphically or mentally by a line. It would seem then that before we can classify faults, we must pay some attention to the classification of fault movements.

We may be able to make the complete measurements, viz., the amount and direction of movement on the fault plane—or perhaps only the vertical or horizontal component can be determined —or again the components perpendicular and parallel to the dislocated formation. All these measurements should have names. Again we may measure merely the distance the two parts of a broken formation have been separated and we may measure this either perpendicularly to the stratum or vertically. We may detect and measure faulting as shown in a section, without being able to determine the movement on the fault plane. Lastly we want names for the shifting of the strata as shown in a horizontal plane (the earth's surface).

It might seem unnecessary to call attention to the various functions of fault movement as they have been so thoroughly explained by Spurr, but I offer as excuse the fact that detailed underground mapping has forced upon me an appreciation of the importance of getting a stereogrammatic conception of fault movement. Spurr's names have priority and the best of authority behind them, but they are neither complete or easy to remember. For instance "lateral separation," "perpendicular separation," and "vertical separation" all lie in different planes. In the list I here offer all measurements on the fault plane are called "displacements." Those on a plane normal to both fault plane and faulted stratum are called "separations." Those shown in any vertical section are called "throws," and those on a horizontal plane (the earth's surface) "heaves."

In defining these functions I assume that the movement on the fault plane is pure translation and that the fault plane is really near enough to a plane to be so considered. Where the plane is distorted and the movement complicated, of course it cannot be defined by simple functions.

In an article published last year I stated "Faults are always measured with reference to the displaced body, and not resolved into horizontal and vertical components, as has been the practice heretofore. It is only by finding a displacement of some such regular body that the fault movement can be measured, and for this and other reasons it is convenient to measure the movement in a parallel and perpendicular direction to the reference strata."[1]

In detailed underground work I have found such a resolution of the movement is most convenient. Jaggar, however, has insisted that vertical measurements are important in triangulating thicknesses, and as cases doubtless arise where the vertical or horizontal component is of interest, I have included such a series of measurements in my list.

I therefore submit the following list of measurements in the hope that it may lead to a closer investigation of the subject and

[1] "Methods of Investigating Problems in Faulting," *Mining Magazine*, February, 1906.

help in the development of a three-dimension concept of fault dislocations.

Displacements—These are the measurements taken on the fault plane. *Total displacement* (*a–b*, Fig. 60) is represented by

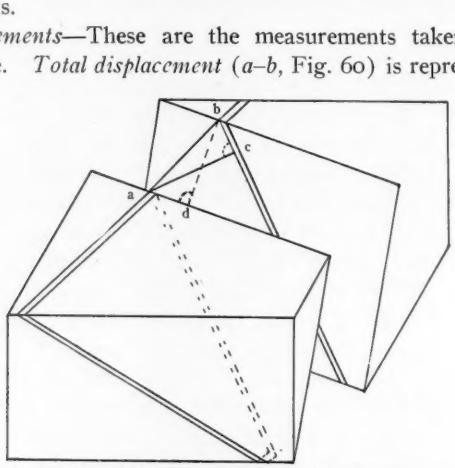

FIG. 60. Diagram illustrating displacements.

a line connecting portions of a faulted bed originally contiguous but now separated by the fracture. Let this line be the hypotenuse of a right-angled triangle, the opposite side of which is perpendicular to the faulted stratum. The adjacent side of this triangle represents the *parallel displacement* (*b–c*) and the opposite side the *perpendicular displacement* (*a–c*).

Construct a new triangle, the total displacement again being the hypotenuse and the adjacent side a horizontal line. The adjacent side may then be called the *horizontal displacement* (*ad*) and the opposite side (*b–d*) the *vertical displacement*.

Separations.—The second set of measurements (Fig. 61) are in a plane normal to both the fault plane and the faulted bed. The measurement most often taken in practice is the perpendicular distance between the two portions of the faulted formation, or portions produced. This is the *perpendicular separation* (*c–d*, Fig. 61). The adjacent side of the triangle (*ad*) is the *parallel separation*. The hypotenuse (*a–c*) is a fault plane measurement, and as such has already been named the perpen-

dicular displacement. The measurements *a–e* and *c–e* may be called respectively *horizontal* and *vertical separation*, the two sides of the triangle being parallel and perpendicular to the horizon.

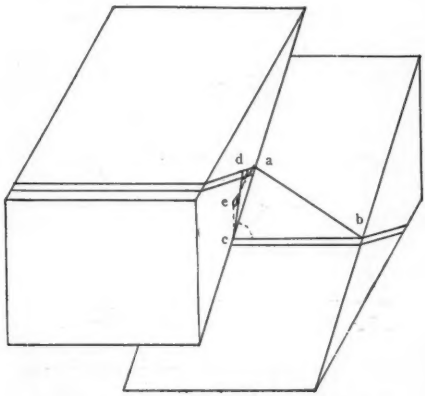

FIG. 61. Diagram illustrating separations.

Throws.—The throws are measurements taken in any vertical section. The most important section in reference to the faulting is of course at right angles to the strike of the fault. To make the classification perfectly definite I suggest that when the term throw is used, it be understood that the section is normal to the strike of the fault. When the throw in other sections is under consideration the statement should be made that section is not perpendicular to the strike of the fault. As shown in Fig. 62, we have *total throw* (*a–b*), *perpendicular throw* (*a–c*), and *parallel throw* (*b–c*); or again resolving into vertical and horizontal components, we have *horizontal throw* (*b–d*) and *vertical throw* (*a–d*).

Heaves.—Finally the heaves are the shifts of the strata shown in a horizontal plane and are named in a similar manner. In Fig. 63 (*a–b*) is the *total heave*, (*a–c*) the *perpendicular heave*, and (*b–c*) the parallel heave. Of course there can be no such thing as vertical and horizontal heave.

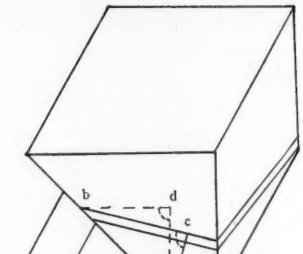

FIG. 62. Diagram illustrating throws.

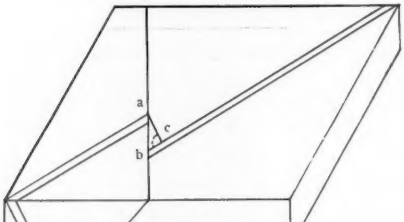

FIG. 63. Diagram illustrating heaves.

Below is a list in which Spurr's names are compared with those here suggested.

SPURR'S NAMES.	NAMES SUGGESTED.
Total displacement,	Total displacement.
Lateral separation,	Perpendicular displacement.
No name,	Parallel displacement.

No name,	Vertical displacement.
No name,	Horizontal displacement.
Perpendicular separation,	Perpendicular separation.
No name,	Parallel separation.
No name,	Vertical separation.
No name,	Horizontal separation.
Throw,	Total throw.
Vertical separation,	Perpendicular throw.
No name,	Parallel throw.
No name,	Vertical throw.
No name,	Horizontal throw.
No name,	Total heave.
Heave or offset,	Perpendicular heave.
No name,	Parallel heave.

C. F. TOLMAN, JR.

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RECENT IMPROVEMENTS IN THE UTILIZATION OF COAL.

DISCUSSION OF PAPER BY M. R. CAMPBELL.

Sir:—Referring to the communication by Mr. M. R. Campbell appearing on page 285, entitled "Recent Improvements in the Utilization of Coal," it would probably have been better had the title read "The Comparative Heat Efficiency of Gas and Steam Power of the Experiment Plant of the Geological Survey." It is not my object, however, to criticize the title, but to call attention to the fact that we have too much argument relative to the comparative heat efficiencies of the two methods of power development and too little data regarding the cost of producing power by the two methods.

Mr. Campbell says, quoting the first line of his paper—"The better utilization of coal and the cheaper production of power are questions of vital interest to almost every person in the country, for the foundation of modern civilization is power," and yet to date, so far as I am aware, no figures have been offered by the Geological Survey, stating cost of power development. The

measure of real efficiency is not a measure of heat utilization, but cost of producing power. If the Survey would redesign Plate II. appearing at page 288, showing comparative heat utilization for producer gas and steam plants, upon the basis of cost per electrical horsepower, it would furnish information of greater value and usefulness than a comparison made simply upon the heat efficiency basis.

Then, again, I do not think it is permissible to consider any recent outcome of producer gas experiments as being in the nature of improvements. It may have been a fact that in the St. Louis tests coal was gasified, which many laymen did not expect could be usefully employed for that purpose, but from the standpoint of those familiar with gas production and gas producer working, it is not permissible to consider such as an improvement.

This matter of improvement, so far as utilization of coal is concerned, is one which may be looked at from two standpoints—that of present economy and that of the preservation of our coal supplies. It would, of course, so far as the future generation is concerned, be highly desirable that gas producers be used as much as possible, thereby reducing the quantity of coal which would be required and saving more for the future. From this standpoint, extended use of gas power could be considered as an improvement, but as far as commercially feasible methods of coal utilization are concerned, the most important recent improvement has been along other lines more especially connected with steam generation. There are two phases of this development—one which relates to the designing of boilers so that a greater quantity of heat will be abstracted from the hot gases, and one which aims by better furnace construction to insure a more complete combustion of the coal. It is probable that in the near future there will be a decided improvement in gas producers, and the outcome no doubt will be that the gas power plant will present itself at a cost sufficiently low to compete with steam plants under various conditions which are not now possible; but at the present time it is difficult to see how, with low-priced fuel, the best gas power plant can compete with the best steam plant.

A. BEMENT.

REVIEWS

Clays, Their Occurrence, Properties and Uses. By HEINRICH RIES, Ph.D. Pp. xvi + 490. 44 plates and 65 figures. John Wiley & Sons, New York, 1906.

"Clays, Their Occurrence, Properties and Uses" is the product of many years study by one of the most prolific writers on the subject in this country. Branner in his bibliography on clays credits him with fifty reports and papers published at different times during the past sixteen years. That the author has written the majority of the State Survey Reports on clays there is no question. Having thus been one of the most prominent writers on clays it is to be expected that his text-book should possess thoroughness and scientific accuracy.

Ceramic literature in English is very much scattered through reports and journals with only here and there anything like an attempt at a thorough treatise either on the clays or the clay industry. Dr. Cook, in the Report on the Clay Deposits in New Jersey, 1878, Professor H. A. Wheeler, in Vol. XI., Missouri Geological Survey, and Mr. Karl Langenbeck in his "Chemistry of Pottery" gave the clay workers the first and probably the best discussions that have appeared in the English language, aside from a few translations from the French and German. Each of the books named, however, is either out of print or is not sufficiently general in scope to be of much value to the largest number of clay workers, hence a satisfactory general treatise on the subject of clays and clay industries would be welcomed by the clay workers at large with more favor perhaps than is usually given a book of similar scope on any other industrial subject. It was in this expectant frame of mind that the reviewer read Dr. Ries's book. After having carefully read the book and reread some of the parts dealing with the technical phases of the

question, the reviewer could not but feel that in it the author has not acquitted himself with justice, for "Clays, Their Occurrence, Properties and Uses" is not up to the standard of thoroughness, accuracy or general plan of presentation set by the author's report on the Maryland clays (Md. Geol. Surv., Vol. 14, Pt. III.). Aside from the fact that it contains an extraordinarily large number of references and that it brings down to date the discussions on many mooted points, the author has failed to produce a book which to the average clay worker is equal in value to E. Bourry's "Treatise on Ceramic Industries" and several other volumes of similar scope.

One not familiar with clays and the clay industry in a practical way could not obtain any more real help from the volume under review than he might from one of the state reports on clays, lamentably weak as most of them are in the description of manufacturing processes. The book will no doubt find its greatest value as an aid to general ceramic engineers, teachers and ceramic investigators. To this class of people it can be used as a ready reference to the published literature and as such would perhaps be worth its cost.

The reviewer does not care to discuss the last half of the book which deals exclusively with the clay deposits in the different states, for he is in doubt as to the value of such a compilation and has not had opportunity to look up the subject matter in detail. The more technical portion of the book, however, was examined at some length.

The purely geological questions, such as the origin or formation of clays, their alterations and transportation, the author has presented in a thorough and orderly manner, giving the later views of geologists on these questions. But even when dealing with these strictly geological considerations he occasionally becomes confused and as a result there occurs a page like 47, in which there are not only irrelevant statements and confused ideas, but also inaccurate citations.

In his discussion of the technical phases of the clay industry the author has relied almost wholly upon compilation and notes

from a large number of sources, and in many places he has pieced these together without displaying originality, or even attempting to harmonize them or to cite evidence for or against the opinions which they express. This is illustrated on pages 72 and 73, where the coloring action of iron oxide on burned clay is discussed. One paragraph is devoted to a summary of Seger's views concerning the calcareous and aluminous buff-burning clays. In the next paragraph is given a summary of Professor Orton, Jr.'s views on this same subject, which are in effect opposed to those of Dr. Seger. The following paragraph then reads: "It would seem, therefore, as if the cause of this buff-burning quality must be sought for in some other direction." The author then drops the discussion only to take it up again on page 162, where he again quotes Seger.

At no place has the author given an example illustrating either Seger's or Orton's views, nor has he touched upon the most important phases of the subject, the relative proportions of Al_2O_3, CaO, etc., which cause the "masking" or "bleaching" of the iron color, and the influence of other factors upon it. Nevertheless he quotes a large number of analyses the only practical value of which might be as evidence upon just such questions as the influence of lime or alumina on the colors produced in burning, and others which are still unsettled. It is unfortunate that he did not make use of these extensive data in discussing the questions in dispute. It seems to the reviewer that this should have been the mission of the writer when presenting his book to the public. Surveys have been collecting analyses of clays for many years and in a considerable number of instances these have been accompanied by statements of their physical and pyro-chemical properties. Very few of the surveys, however, have drawn many conclusions of technical or practical value from the facts put forth. A collection and correlation of this scattered data from the surveys would be a contribution to our literature that would be worth the time and energy expended upon it. It was hoped that the present volume would attempt such a discussion. Its author had written seven

or eight reports for state and federal surveys which have been distributed either free or at a nominal price so that every clay worker who desired them has been able to secure one copy. It is a matter for surprise, therefore, to find this text-book merely a compilation of what has already been published and nothing more.

This being the case, it is unfortunate that there was not more judgment displayed in the selection and arrangement of the matter presented, so that there might be fewer conflicting views expressed, without intimation as to which seemed the most reasonable, and that there might be a more logical sequence in their order of treatment. An illustration of the confusion arising from the undigested manner in which various views are presented is seen in the treatment of the term *sand*. After defining "sand" on page 69 as including "quartz and silicate minerals other than kaolinite, which are not decomposable by sulphuric acid," on subsequent pages (170, 132 and 173) the term is used in either an indefinite sense or as a synonym of silica—or at any rate to one not versed in chemistry this would be the interpretation that would be placed on such a statement as the following: "The effect of silica has not always been understood by fire-brick manufacturers, many believing that sand added to the refractoriness of a clay in burning" (p. 173).

A more serious criticism of the book relates to its careless presentation of the views of other writers, especially those of Dr. Seger on the fusibility of Al_2O_3—SiO_2 combinations. On pages 140 and 173 the classic experiments of this investigator are referred to, but his results are misinterpreted, and there is given a surprisingly peculiar explanation of a chemical formula. After the symbol Al_2O_3, 17 SiO_2 there is placed in brackets the expression (1:9 by weight) and further (on page 173) he states in a footnote, "parts by volume would not be the same as parts by weight, because the two substances have different specific weights, hence 1 alumina to 1 silica per volume would be 91.5 per cent. alumina to 9.5 silica by weight."

This interpretation of a chemical formula, and especially the

inference as to the manner in which Seger compounded his mixtures of Al_2O_3 and SiO_2, were so radically different from anything the reviewer had heretofore seen on the subject that he dropped a line to Professor Bleininger, the editor of the American Ceramic Society's translation of Dr. Seger's collected writing and asked for his interpretation of Seger's description of his experiments. In reply he received a letter stating that Seger's original article had been reëxamined and that in it nothing could be found that could possibly be construed as meaning anything but that the mixtures used by Seger were compounded by weight in the molecular proportions indicated by the formula $Al_2O_3 \cdot 17SiO_2$.

In addition to the misconstruing of Dr. Seger's statements, the author has taken the liberty of drawing Seger's Al_2O_3—SiO_2 curve in a manner very different from that found in the original paper, a reproduction of which can be found on page 345, Vol. I., of the American Ceramic Society's translation of Seger's collected writings. The most deceptive part of the new curve as drawn by Ries is the placing of the point of maximum fusibility on the abscissa that corresponds to a mixture of *10 per cent. of kaolin or alumina and 90 per cent.* SiO_2. To those familiar with the fusion behavior of Al_2O_3—SiO_2 mixtures, the statement that 10 parts by weight of *kaolin or alumina* to 90 parts by weight of SiO_2 give the mixture having the maximum fusibility serves only to disclose the inaccuracy of the author's statements. In fact, one need not be familiar with the problem to understand that the lowest fusing point of kaolin-quartz on the one hand and alumina-quartz on the other, are not attained with the same proportions in each case. In the latter case the mixture giving the maximum fusibility is approximately 1 to 10 by weight while the ratio of kaolin to silica giving maximum fusibility is approximately 1 to 3.51 by weight, or 22.2 per cent. kaolin + 77.8 per cent. SiO_2.

The author's presentation of the results of Seger's Al_2O_3—SiO_2 fusion curve is the most glaring irregularity in the book and it must certainly throw doubt on the value of the author's

own experiments cited on page 174, indeed if not on most of his researches.

Perhaps no further illustrations of the author's method in discussing the results of other investigators is necessary. However, we cannot pass over without comment the inconsistencies that are revealed upon a careful comparison of the statements concerning Wheeler's objections to the Bischof formula as given on page 146. From the remarks on this page it must be inferred that the author agrees with Wheeler in the objections he makes, and yet on page 145 he makes statements that are directly opposed to those of Wheeler. Moreover, he not only gives Seger's substitute for the Bischof formula incorrectly but presents it in a form different from that given in the article he cites, viz., "Collected Writings of Seger," translation, 1, p. 486, 1902.

The redeeming features of the book are (1) its copious references and (2) the collection in one volume of the main features of valuable scattered articles.

ROSS C. PURDY.

UNIVERSITY OF ILLINOIS.

In view of the somewhat sweeping condemnation contained in the foregoing review, it seems to the editor that, in justice to Professor Ries a more favorable estimate which has recently been received should also be published. Accordingly a second review will appear in the following number of this journal. The importance of the work justifies this full presentation of its merits and defects.

Joplin District Folio. By W. S. TANGIER SMITH and C. E. SIEBENTHAL. U. S. Geological Survey, Folio No. 148, 1907.

This folio, which is the result of field work carried on by W. S. Tangier Smith and C. E. Siebenthal at various times since 1901, contains a general discussion of the stratigraphy, structure and ore deposits of the well-known Joplin district. In the introduction there is given a general summary of the topography and geology of the Ozark plateau region. The generalized sections of the Ozark plateau are poorly constructed, representing very crudely the stratigraphy and structure of the region. In general

the limestones of the Joplin district are non-magnesium, as stated by the authors, although there are certain horizons within the Carboniferous in which the beds are distinctly dolomitic.

In a discussion of the topography of the region, the upland plains and the drainage are discussed in some detail. In connection with the discussion of the drainage, the authors say: "In no case, with the possible exception of Shoal Creek, do these courses appear to have been determined by lines of weakness in the underlying rocks, such as folds; nor have they apparently been influenced by the many small shale areas found over the district. . . . In some instances, however, according to Bain, the stream courses follow zones of fracturing, which may or may not be accompanied by faulted masses of Cherokee shale lying below the general level of the upland. . . . Shale areas not connected with zones of fracturing, but filling pre-Cherokee erosion hollows, may also have been effective in directing the flow of some streams." In connection with the discussion of the valley tracts, the terraces and alluvial slopes, so well recognized in the district, are described.

The section devoted to the stratigraphy conforms in general with that which has been outlined by the Geological Survey of Missouri. The Burlington and Keokuk limestone, however, are grouped together under the name of the Boone formation. In this formation two well-recognized horizons are distinguished and named respectively the Grand Falls chert and the Short Creek oölite. At Grand Falls, the locality from which the Grand Falls chert is named, the chert is unusually thick and massive. As far as our observations have gone, this occurrence is exceptional rather than typical. As stated by the authors, it is sometimes difficult to distinguish this horizon from others in the Boone formation except when considered in its relation to the Short Creek oölite, which is thought to occur uniformly about 100 feet above. In discussing the character of the chert, reference is made to a gnarled and knotted variety which the authors believe to have been the result of "rather sharp deformation instead of simply brecciation." The only apparent justification

in attributing this gnarled structure to deformation is the inability to find any other seemingly adequate cause. I have had the impression that this structure was due to original rather than secondary causes.

The top of the Grand Falls chert is thought by the authors to be coincident with the top of the sheet ground and it appears that the Grand Falls member has been mapped over the district chiefly upon this assumption.

The Short Creek oölite is a well-recognized horizon and was used by me and my assistant in working out the structure of the Granby area. It was also recognized by the earlier geologists. The resemblance which this oölitic limestone bears to the Spergen formation of St. Louis county is indeed striking, as pointed out by the authors of this folio.

An unconformity is recognized between the Boone formation and the Carterville, which has been mapped as occurring in twenty-three localities over the district. The age of the Carterville is shown to be Chester by its fauna. Although no reference is made to the fact in this folio, Professor G. C. Broadhead, in an early report of the Missouri Geological Survey, recognized the presence of a sub-Carboniferous fauna in quartzite underlying the Coal Measures strata of this district.

The Carterville formation is separated from the Cherokee and Boone formations by unconformities.

The Cherokee in this district is estimated to have a thickness of not over 150 feet and belongs to the Lower Coal Measures, probably somewhere about the middle.

Above the Cherokee, the authors recognized the Lafayette gravels of the Tertiary and soil, alluvial and terrace deposits belonging to the Quaternary.

In their discussion of the stratigraphy, reference is made to the buff-colored, massive-bedded, finely-granular and non-fossiliferous dolomite. Following Broadhead, the authors believe that this magnesian limestone is a result of local dolomitization. In connection with the Boone, it is pointed out that there is a system of close-set parallel fracturing more or less at right angles

to the bedding, which in many places completely obscures the stratigraphy and breaks up the heavy chert beds into highly inclined sheets. This type of chert is referred to as "sheeted chert." In referring to the Grand Falls chert, reference is made to what is known as "butcher knife" flint. It is believed by the authors that this flint has been thoroughly crushed and later recemented with a dark bluish, siliceous cement. No reason is given for believing that this brecciation is due to crushing.

Considerable space is devoted to the structure of the region. It is pointed out that the unconformities are of a peculiar type characteristic of cave-region topography. They are characterized as solution unconformities and in this connection they follow the results of the investigations of the Missouri Geological Survey, especially the work of Schmidt, Winslow and the present corps.

Only two faults, having displacements of 35 feet and 25 feet respectively, were recognized in the district. These faults were only inferred from the records of drill holes, and as any one who has worked in the district knows, drill records in this region cannot be relied upon for the purpose of determining structure. In connection with the discussion of faulting, the authors say, "The slickensided limestone walls, the broken character of the shale at the steeper peripheral contacts of the shale patches, and the local zones of brecciation, which have led to the ascription of deep faulting to the Joplin district, and have introduced such confusion into its structural geology, are no doubt due to such readjustments." In this the authors refer to the effect of solution in permitting the settling of large blocks that accompany brecciation of the chert bed. It is worthy of note that deep faulting in this region is not recognized in any of the reports of the Missouri Geological Survey. Perhaps reference is here made to late reports of the United States Geological Survey.

The brecciation in this district is discussed somewhat at length. The authors recognize the basal breccias, which in the Granby report were called the "Granby Conglomerate," sheet breccias and zonal breccias. It is pointed out that the basal breccia cor-

responds to a basal conglomerate, as described in the report on the Granby Area published by the Missouri Geological Survey. The authors attribute the sheet breccias which occur chiefly in the Grand Falls chert to gentle warping. Associated with these breccias occur secondary chert, which the authors believe to be a metasomatic replacement of limestone. This secondary chert is spoken of as "jasperoid." It is stated that the so-called zonal breccias are in contact with and grade into basal breccias, and from the description it is apparent that one would have some difficulty in recognizing the distinction in the field.

The authors have introduced an illustration (Fig. 4) to show the methods of brecciation in the Boone formation. This illustration is purely theoretical and no specific example is cited in which this is known to have occurred. This illustration shows a shale pocket, which, after deformation, occupies about three fourths of the space which it occupied originally. If this shale was subjected to horizontal thrust, as indicated, the shale would probably have been pushed up at the surface and undoubtedly there would have been greater deformation of the chert and limestone horizons underlying it. This illustration does not show the result of compressive stresses which one might expect and it is doubtful if such a condition actually exists in the Joplin district.

The authors discuss in detail the deformation of special areas referring particularly to the so-called "Cornfield Tract." This they say exhibits the most decisive evidence of deep faulting that the district affords. However, at this place, the authors were unable to figure out, as a result of both folding and faulting, a displacement of more than 25 feet.

The report contains a very excellent illustration of a well-known shale pocket near Carthage which had a very rich ore body at its base. The ore occurred in the basal breccia. This ore body is in no way connected with deep faulting and it is a little difficult to understand how an artesian circulation could supply the lead and zinc salts required for its formation.

Some of the ore bodies occur in a form known as "circles."

The authors accept the explanation of Schmidt and Winslow to account for this shape. The explanation given by Bain that they are due to intersecting faults is clearly disproved by the illustrations cited in this folio.

The section on structure is followed by another on Historical Geology, in which the authors have reviewed the well-known successive periods of erosion and sedimentation.

The section on economic geology deals chiefly with the deposits of lead and zinc ore, their composition, paragenesis, geographic and geologic formation, vertical distribution and genesis. In the discussion of the minerals of the ore deposits it is said, "The lead ore minerals comprise galena, in the belt of cementation below ground-water level, and a limited amount of cerusite, in the belt of weathering above that level." This is undoubtedly, in a large measure, true of the present condition of the mining in this district. However, in the early days, mining was chiefly above the level of ground-water and from this superficial zone great quantities of galena were mined. The statement that the zinc ores consist chiefly of sphalerite in the belt of cementation, with a minor proportion of smithsonite and calamine above the ground-water level, is more nearly correct. However, in this case, also, it must be recognized that a considerable tonnage of zinc blende has been mined above the level of ground-water.

The descriptions of lead, zinc and other minerals, is such as one ordinarily finds in connection with a report of this character. The bitumen known as "tar" by the miners is thought by the authors to have had its origin in the Boone limestone. I have seen no proof of this in my investigations in that district. On the contrary, it is well known that the overlying Cherokee formation is everywhere impregnated with bitumen. A short distance northwest of this district the sandstones and shales of this formation contain as much as 12 to 15 per cent. of a heavy asphaltic oil. It is thought that through the breaking up of the shale and sandstone beds, as a result of settling of the underlying limestone and flint, avenues for the passage of the bitumen into the Boone formation have been provided. Every evidence seems to indicate

that the bitumen in the Boone formation has been chiefly derived from the overlying Cherokee formation.

In the description of the minerals no mention has been made of the beautiful crystals of ferrous sulphate and magnesian sulphate which form abundantly in some of the mines. Crystals of ferrous sulphate one to one and a half inches in diameter were taken from one of the mines on the land owned by the Missouri Lead and Zinc Company of Joplin.

The paragenesis of the minerals is essentially the same as that observed in our investigations in the district.

The term " jasperoid " is applied to what is known throughout the district as secondary chert. I do not quite understand the necessity for giving this chert a special name. Its composition is not different from that of ordinary chert and it would be difficult for one to distinguish it except through its association with chert of other generations. The senior author of the folio believes that this secondary chert is a metasomatic replacement of the limestone. This may be true in some instances, but I am inclined to believe that it is a mechanical deposit which has been silicified through the introduction of circulating waters carrying silica in solution. This point, however, requires additional investigation.

The so-called selvage is mentioned as grading into jasperoid and the senior author believes that it is simply a weathered form of this secondary chert. The authors also note the occurrence of dolomite grading into limestone and also secondary limestone cementing chert breccias.

The Cherokee shale of this district is found in openings in the Boone formation and it is thought by the authors to have been either dragged down along planes of faulting or entrained by underground water. In view of the fact that the authors were able to find only two faults of small magnitude, it is rather difficult to understand how the shale could have been dragged down along fault planes, especially where it occurs at a depth of 150 to 200 feet. In the report on the Granby Area, the opinion was advanced that the shale was carried in suspension by ground

waters. The impalpable character of the clay and quartz formed through the weathering of shale would find its way through the finest seams and cracks in the rocks extending to very considerable depths.

The authors state that the forms of the ore bodies fall into two general groups, the first including runs and their modifications, the second consisting of blanket veins. This classification coincides with the observations of most persons who have investigated the district.

The authors also recognize a zonal arrangement of the ore bodies. A mapping of the mines of the district indicated that the ore bodies occur in belts which in general have a trend west of north. Some of the belts trend north and south and northeast, but up to the present none have been found to have an east and west direction. These belts are intimately related to the structure which in turn has been controlled by solution and accompanying brecciation. Six belts have been recognized and described, known as the Joplin belt (this is a double belt), the Webb City belt, the Galena belt, the Central City belt, the Villa Heights belt and the Alba-Neck City belt. One would infer from the text that the authors do not believe that the intermediate areas will ever be ore-producing. It is interesting to note that they have gained an impression that other belts may be found to the westward and that the present belts may be extended along the direction of their strike.

In their discussion of the geological relations of the ore bodies, reference is made to "The close and fairly constant association of the ore deposits with the valleys and likewise with the depressed patches of shale." It is further noted that the solution breccias have controlled the location of valleys and shale patches; and that "Zones of brecciation and solution are plainly independent of the deformational features represented by the structure contours on the economic geology map." It is said that "The controlling factor in the location of the ore deposits has been the existence of breccias."

Referring to the vertical relations, it is said that "Aside from

the effects of oxidation, the most noticeable feature of the vertical distribution of the ore runs is the frequently observed abundance of galena in the upper parts of the deposit, with little or none in the lower levels. . . . This is the same both in runs lying partly within the zone of weathering and in those lying wholly in the zone of cementation, . . . which have never, so far as known, been associated with higher ore bodies." Again it is said that "For this reason the relation is believed to be that normal to a first concentration of the ores." "Neither galena nor sphalerite can be said to be dominant in general at any given horizon in the Boone formation, and in the Cambro-Ordovician rocks, as shown by deep drill holes, both ores are found to a depth of at least 700 feet." With regard to the presence of iron sulphide, it is said that "The distribution of marcasite in the runs appears to follow no rule, being here uniform, there irregular, and in general variable from point to point. The greatest development is in the Cherokee shale."

It is noted that there is no well-defined horizon except that of the sheet ground and that the ore bodies occur chiefly above the base of the Grand Falls chert at a depth not to exceed 250 feet. The authors say: "It seems probable to the writer that but little ore will be found in the Boone formation below the Grand Falls chert, and that what is found in depth may be expected chiefly in the Cambro-Ordovician rocks."

Reference is again made in this connection to the close relationship existing between the ore bodies and the areas of overlying Cherokee shale. This has been pointed out by other authors, attention having been especially called to this point in the report on the "Geology of the Granby Area."

Perhaps the most interesting and important phase of any discussion of this district is that which deals with the genesis of the ores. In this folio the Bain-Van Hise theory is accepted with very few modifications. The authors give greater importance to the ascending solutions, claiming that the ore bodies as they occur to-day are in the main a result of an ascending, deep-seated circulation.

In spite of the acceptance of the theory of an artesian circulation to account for, the first concentration, the authors say: "There are, so far as known, no well-defined horizons of circulation in the rocks underlying the district, and there is no direct evidence to show from which of the sedimentary formations the ore-bearing solutions were derived. The determination of the exact source of these solutions must, therefore, be indirect and, to some extent, a matter of conjecture."

Farther on the authors say: "The locus of the deposits in the Boone formation is a result of the conjunction of chemical and physical environment especially favorable to their deposition. . . . The widespread dislocations and brecciations of the Joplin district have allowed a commingling of the waters not only from different parts of the Boone formation, but probably also from the Cambro-Ordovician. Through these openings and through the areas where shale is absent below the Boone, the deep-seated waters rise toward the surface and mingle with the circulating waters of that formation. . . . The amount of hydrocarbons contained in the Cambro-Ordovician rocks is undoubtedly adequate for ore precipitation where other conditions are favorable. . . . In other words, in the Joplin district the concentration of the ores has taken place, not where the chemical conditions alone are favorable, as appears to be the case throughout those portions of the Boone formation where limestone is present, nor even where they appear to be most favorable; but only where the physical conditions likewise are especially suitable. . . .

In a discussion of the chemistry involved in the precipitation of the lead, zinc and other associated minerals, it is said that "With the continued limestone solution consequent on this, the waters would become practically saturated with calcium salt, resulting finally in the precipitation of the calcite." Further, it is stated that the "dolomite, jasperoid, and disseminated sphalerite were all evidently in process of formation at the same time, and this continued till the practical completion of the dolomitization and silification of the limestones adjacent to fault planes at the horizon of brecciation."

Referring to the presence of hydrocarbon compounds, they say that "These compounds probably occur in quantity adequate for sulphide precipitation in all the sedimentary formations from the Cherokee to the base of the series."

In a discussion of the secondary enrichment of the ores, the authors say: "Aside from the small and unimportant amounts of sulphides unmistakably due to second concentration, which have just been described, the recognition of sulphides deposited by descending waters is generally a difficult matter, both because they have been formed in the same way as the ores of first concentration—in the same place and by the same reducing agents—and because they occur merely as accretions to the older deposits. . . . In all instances noted by the writer, where sulphide enrichment had apparently taken place, the amount of this enrichment, so far as it could be determined, was small as compared with the volume of the ores of first concentration, and generally of small economic importance."

The most interesting phase of this discussion is the acceptance of the Bain-Van Hise theory of a first concentration through an artesian circulation in the face of the fact that the authors were unable to corroborate in the field any of the essential facts upon which Bain and Van Hise based their theory. The authors have shown the absence of deep-seated faulting which might establish a free circulation between the Cambro-Ordovician and the upper part of the Boone formation. They also point out that the source of the magnesia required to account for the dolomite has no bearing on the origin of the ores, as has been claimed by Bain. They have attributed the existing vertical distribution of the sulphides, galena at the top with zinc blende and iron sulphides below, to the first concentration, while Bain and Van Hise attributed it chiefly to a second concentration. Were the authors of this folio to study carefully the chemical processes by which such an arrangement might be brought about, they would find that the succession of ore deposits in this district could not be evolved from an artesian circulation without involving an almost complete reconcentration through a descending circula-

tion; the present vertical arrangement of the sulphides being that which would naturally result from precipitation by a downward circulation. If, as the evidence goes to show, 75 per cent. of the galena occurs directly beneath the pre-Pennsylvanian erosion surface of the Boone formation, it could only have attained that position by downward circulation from some superimposed formation now removed. This condition is fully discussed in the report on "The Geology of the Granby Area," Vol. IV., 2d series, of the Missouri Bureau of Geology and Mines.

The authors have not attempted to determine the presence of lead and zinc salts either in the overlying Cherokee shales or in the circulating ground waters of the shallow and deep wells. It might, however, have been pointed out that such analyses as have been made thus far go to indicate that lead and zinc salts are not being carried at present by the waters from the Cambro-Ordovician, but that it is generally present in considerable quantity in the water descending from the surface. This in itself is a strong argument against the artesian theory of the origin of the lead and zinc ores of this district.

This folio includes a discussion of the building stone, lime, coal, clay and water resources of the area. The treatment of these resources is brief, but shows in the main the wealth of the agricultural and other resources depending upon the soils, rocks and clays for their maintenance.

E. R. BUCKLEY.

ROLLA, MISSOURI,
July 12, 1907.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

G. F. Loughlin and A. H. Hughey.

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SCIENTIFIC NOTES AND NEWS[1]

THE DIVISION OF MINES, Philippine Islands, is contemplating the sending of an expedition during the next five or six months to make a preliminary mineral reconnaissance of Mindanao. This party will consist of one geologist, one mining engineer and one topographer, and it is hoped that the military authorities will coöperate in this work which ought to mean much to the Moro provinces. Besides making geological reconnaissances, route maps, etc., it is the intent of the members of the party to visit every locality where bona fide prospecting and development work has been carried on.

The telluride of gold—calaverite—has been positively determined by the division of mines in some specimens recently brought in by Dr. Fairbanks. The specimens are known to have come from the gold mining district of Southern Lepanto. This is the first authentic report of telluride in the Philippine Islands.

PETROLEUM HAS BEEN FOUND in three places in the Philippine Archipelago: one in Tayabas Province, the other two on the island of Cebu; one near the center of the island on the west coast not far from Toledo, the other near the southern extremity, very close to the pueblo of Alegria. At Tayabas and at the first named locality in Cebu some prospecting by means of boring has been carried on, but the Alegria field remains practically unknown. The oil in all three localities is found in a bluish shale, presumably of Tertiary age.

DR. CHARLES A. DAVIS, of the University of Michigan, who has recently completed a report on the peat deposits of Michigan, has been engaged by the United States Geological Survey to

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

make a reconnaissance survey of the peat formations of the coastal plain from the Carolinas northward during the summer.

THE FEDERATED MALAY STATES have a geological survey and a report of progress covering the period from September, 1903, to January 1, 1907, has just been issued by Mr. J. B. Scrivenor, the geologist in charge.

STATE GEOLOGICAL SURVEYS have recently been established in Colorado, Arkansas and Florida.

PROFESSOR ANDREW C. LAWSON, of the University of California, is still in Washington, D. C., finishing the report on the San Francisco earthquake. Professor Lawson is chairman of the State Commission for the investigation of the earthquake. The report will be published by the Carnegie Institution.

MR. S. T. EMMONS, of the U. S. Geological Survey, left Washington on July 12 to carry out some private investigations of the copper deposits of Cananea, Mexico. He will be assisted in this work by Mr. L. C. Graton.

MR. BAILEY WILLIS, of the U. S. Geological Survey, has gone to Europe under the auspices of the Carnegie Institution to study the structure of the Alps.

THE PENOBSCOT BAY FOLIO, Maine (No. 149), has just been published by the U. S. Geological Survey. The geologic map is the work of Messrs. Geo. Otis Smith, E. S. Bastin and C. W. Brown. The granite quarries are the most important mineral resource. There are also clay deposits and old, now abandoned, copper mines at Bluehill and Brooksville.

THE PISGAH FOLIO, North Carolina (No. 147), is another recent publication of the same bureau. The geologic work was done by Mr. Arthur Keith. The quadrangle embraces parts of the Blue and Pisgah ridges, between which flows the French Broad River. The mineral resources are not of great importance, but include building and ornamental stones, talc, mica, corundum, kaolin, clays, lime, graphite, copper and gold.

THE DEVIL'S TOWER FOLIO, Wyoming (No. 150), also just issued, covers a part of northeastern Wyoming in Crook County.

The mineral resources include building stones, clays and gypsum. The prospects for obtaining artesian water at many places are shown to be good.

THE DIVISION OF MINERAL RESOURCES of the U. S. Geological Survey announces the following preliminary statistics of production in 1906:

	Quantity.	Value.
Pig iron, long tons	25,307,191	$505,700,000
Aluminium (lbs.)	14,910,000	4,262,286
Gypsum (short tons)	1,540,585	3,837,975
Sheet mica (lbs.)	1,425,100	252,248
Scrap mica (lbs.)	2,978,000	22,742
Monazite (lbs.) (North and South Carolina)	847,275	152,560
Zircon (lbs.) (North Carolina)	11,000	248
Salt (barrels)	28,172,580	6,658,350
Asphaltum (short tons)	116,653	1,066,019
Coal, bituminous (short tons)	342,848,387	381,122,095
Coal, anthracite (long tons)	63,645,010	131,917,694
Copper (lbs.)	906,591,947	
Lead (lbs.)	695,390,000	
Zinc (lbs.)	399,388,000	

THE FOLLOWING TOPOGRAPHIC WORK by the U. S. Geological Survey is in progress:

Two topographic parties are in Alaska, making detailed maps of the Fairbanks region and of Kasaan Peninsula, on a scale of an inch to the mile, and later in the season the region lying between the International Boundary west of Dawson, Y. T., and Fairbanks, adjoining the southern boundary of an area already mapped, will be surveyed for mapping on the scale of one half inch to the mile. In Arizona the topographic mapping of the Chiricahua quadrangle will begin this fall. In California a topographic survey of an area of about eight miles wide along the foothills on the west side of the San Joaquin valley, including the Coalinga oil fields on the north and the Sunset oil fields on the south, is being made by E. P. Davis. The Big Bar quadrangle, in the Trinity Forest Reserve, is being surveyed by John P. Harrison. A survey of the Meadows quadrangle, in the Wieser Forest Reserve, Idaho, is being made. Later in the sea-

son triangulation will be extended over the Montpelier quadrangle, in the southeastern part of the State. In Missouri topographic work on the Wyandotte (Mo.-Ind. Ter.) quadrangle will be finished in July, when the mapping of the Ste. Genevieve Special sheet and the quadrangle immediately south of it will be started. In Montana topographic surveys are in progress on the Sapphire quadrangle, on the Nyack quadrangle, and on the Glendive quadrangle. Work in the Missoula region will be started on the completion of the Sapphire quadrangle. The Mount Baker quadrangle, bordering the Canadian boundary in the Washington Forest Reserve, is to be mapped by Robert Muldrow. In Nevada a reconnaissance survey extending north from the Tonopah and Manhattan mining camps is in progress. The Silver City and the Gallina quadrangles, New Mexico, are being surveyed. On completion of the Silver City work a special map of the Santa Rita mining district will be made.

OTHER STATES IN WHICH TOPOGRAPHIC WORK is being done are as follows:

Alabama—Opelika, Montevallo and Leale quadrangles.

Colorado—Livermore, Durango, Colorado Springs and Mount Jackson quadrangles and Pikes Peak special map.

Georgia—Acworth and Columbus quadrangles.

Minnesota—Rockford quadrangle.

North Carolina—Gaffney quadrangle.

South Carolina—Salemburg and Gaffney quadrangles.

Tennessee—Franklin quadrangle and Ducktown special map.

Texas—Linden quadrangle.

Virginia—Fricastle quadrangle.

Wyoming—Gros Ventre quadrangle.

Wisconsin—Cross Plains and Oconomowoc quadrangles.

IN CALIFORNIA, ILLINOIS, Indiana, New York, Ohio, Kentucky, Maine, Maryland, Michigan, Mississippi, Oklahoma, Pennsylvania and West Virginia topographic work is to be carried on in coöperation with the state organizations as follows:

California—Woodbridge, Lockford, Galt and Hatchville quadrangles in the Sacramento Valley.

Illinois—Thompsonville, Herrin and Murphysboro quadrangles.

Indiana—Bloomington and Saline quadrangles.

New York—Cooperstown and probably other quadrangles.

Ohio—Ottawa, Continental, Columbiana, Lisbon, McClure, Napoleon, Defiance, Sugar Grove, Logan, Thurston, Fawnville, Newark, Granville and Frazeydrug quadrangles.

Kentucky—Providence, Madisonville, Earl, Central City, Hartford and Whitesville quadrangles.

Maine—Poland and Eastport quadrangles.

Maryland—Mount Airy, Jimsville and Seneca quadrangles.

Michigan—Howell and Milford quadrangles in the southern peninsula.

Mississippi—Inka quadrangle and the Yazoo delta.

Oklahoma—Luther, Merrick, Newalla, Burnette and Norman quadrangles.

Pennsylvania—Gettysburg, Chenango and Valier quadrangles, with probably others to be announced later.

West Virginia—Wayne, Midkiff, Stalbans, Charleston and Clendenin quadrangles.

OF THE EIGHT known important productive oil districts in California five have been the subject of investigation by the United States Geological Survey. Reports on three of these—the Santa Clara Valley, the Los Angeles and the Puente Hills—have recently been published in the Survey's Bulletin 309, and reports on the Santa Maria and Summerland districts will go to press this summer. Of the other three districts, the Kern River has reached a high stage of development, and its limits have been pretty sharply defined by test drilling; the Coalinga and McKittrick-Midway-Sunset fields, after a long period of depression, are being watched with renewed interest. Considerable development work is being done and much is planned for the near future, while the probability of obtaining remunerative wells in the region surrounding the proved grounds is receiving careful attention. It is for this reason that, in making plans for field work for 1907–08, the examination of the Kern River dis-

trict was postponed in favor of the Coalinga and McKittrick-Midway-Sunset districts. The work was assigned to Ralph Arnold, and Robert Anderson was detailed as his assistant. The work is similar in character to that done last year in the Santa Maria oil field, and its results will be given in a comprehensive report on the district, to be published in 1908.

THE INVESTIGATION OF THE MINERALS of the copper deposits of Michigan is being continued this summer by Professor Charles Palache, of Harvard University, for the U. S. Geological Survey. Mr. Palache expects to finish this work before the close of the field season.

THE KNOWN STEEL-HARDENING METALS, named in the order of importance of production and use, are nickel, chromium, manganese, tungsten, molybdenum, vanadium, titanium, cobalt and uranium. The value of these metals produced in the United States in 1906 amounted to $458,327, of which $393,667 was for tungsten. The price of tungsten, which has been increasing for a number of years, was quoted at $5 to $6 per unit (1 per cent. of a ton) in 1905, and at $12 per unit in the spring of 1907. Only small quantities are at present imported into the United States, as European markets utilize practically all that is produced in foreign localities, mostly in Peru and Australia. Large deposits of tungsten are found in Australia, and it is not improbable that sufficient may be obtained there to permit a certain portion of it to be shipped to the United States, but for the present this country will have to look within its own borders for sources of supply. The increased demand for the steel-hardening metals has stimulated prospecting for the ores in the United States, and information concerning them is eagerly sought. So many inquiries have reached the U. S. Geological Survey that a special investigation of the subject has been planned, which has been assigned to Frank L. Hess. In the course of this work, which will extend throughout the summer and into the fall, Mr. Hess will visit South Dakota, Colorado, Montana, Utah and Arizona. The results of Mr. Hess's work will be reported in a bulletin on the steel-hardening metal deposits other than manganese.

IN THE COURSE OF coöperative investigations between the Maine State Survey Commission and the United States Geological Survey, E. S. Bastin of the National Survey devoted some time to a study of the Maine pegmatites, and his report on the geographic distribution, geologic occurrence, origin, characters, uses, methods of mining and manufacture, and commercial availability of the feldspar is published by the Survey as part of its annual economic bulletin, No. 315.

DR. THOMAS L. WATSON, of the Virginia Polytechnic Institute, has been called to the chair of economic geology at the University of Virginia.

PROFESSOR JOHN D. IRVING, of Lehigh University, is at present in Alaska. He has accepted a call to the professorship of economic geology at Yale University and will move to New Haven in the autumn.

DR. DAVID T. DAY, who for twenty-one years has had charge of the preparation of the Survey's annual report on the mineral resources of the United States, has requested to be relieved of duty as chief of the division of mining and mineral resources, in order to devote his time to the preparation, for the Survey, of an exhaustive report on the petroleum resources of the United States. The Director has accepetd Dr. Day's resignation, which will take effect August 1, and has designated Mr. Edward Wheeler Parker to succeed him as chief of the division of mining and mineral resources.

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